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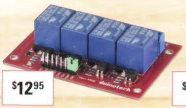

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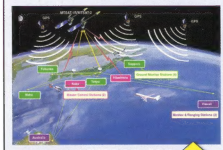

Augmented GNSS (of which GPS is but one variant) uses multiple methods to correct errors, making navigation systems very much more accurate – Page 14

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Editorial Viewpoint

Streaming will make broadcast television obsolete

A "crystal set" radio would have been the first electronic device that most hobbyists built in the 50s and 60s, back when Electronics Australia was known as Radio & Hobbies. They changed their name to Radio, TV & Hobbies in February 1955, to reflect the increasing popularity of television, then again in April 1965 to Electronics Australia.

Radio was pretty amazing technology when it was first introduced and had little competition for home entertainment until television came along. While TV has never had the same DIY culture as radio (building a TV is hard!), it was still a very widely used technology from the 60s to the digital age.

But the march of technology is relentless and these days, notebooks and smartphones have replaced TV for many younger people. When you have 24/7 access to a device which gives you instant access to a huge amount of content on a broad range of topics, why would you want to watch whatever happens to be on TV?

That is why I believe that many free-to-air television channels are going to disappear over the next couple of decades. There will probably still be news and sport broadcasts, at least for a while, but most other entertainment programs will be streamed on-demand. Streaming makes it much easier to cater to niche interests.

If you want access to mainstream movies and TV shows, services like Netflix, Amazon Prime and Stan are pretty cheap, at around $10 per month. That's small change in most budgets and is good value when you consider that you can watch a wide range of programs at your convenience. And as the NBN is completed (eventually!), the average person will have enough bandwidth for HD streaming.

I particularly like free streaming services such as YouTube. Now that we have a proper "Smart TV" at home, which can browse and view YouTube videos, my family rarely bothers with broadcast TV any more. We go straight to YouTube to watch videos that interest us; programs which the free-to-air broadcasters would never broadcast.

For example, there are hundreds of videos suitable for very young children on YouTube, which is much more suitable than the programming on the ABC Children's TV channel. And my wife likes cooking but she usually finds the programs on the SBS Food Network uninteresting. By comparison, there are plenty of great food and cooking shows on YouTube.

YouTube videos do not always have the best production values (you may be surprised!) but we find them more interesting and entertaining and that's what really matters. The ad breaks are shorter and we also have the convenience of being able to pause the show, or turn the TV off and finish watching later.

And YouTube has plenty of electronics-related videos; something you will not find on broadcast TV. One popular channel is EEVBlog by Sydneysider David L. Jones, a past contributor to SILICON CHIP. He has more than half a million subscribers and some of his videos are really interesting. If you haven't seen them, you should take a look.

While "Freeview" does offer some streaming of broadcast TV content, I find it quite glitchy and the content is limited. I am not sure it will be enough to save the networks. They are going to have a hard time as younger generations will not watch TV like their parents.

Like the music and newspaper industries, TV broadcasters will need to adapt to the new technology to survive.

Nicholas Vinen

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Modern vehicles have difficulty charging caravan batteries

Regarding modern vehicle sporadic battery charging, I have discovered another trap for those towing caravans that use the vehicle to power a fridge and charge house batteries while driving.

My uncle purchased a 2018 Isuzu D-Max to tow his caravan. The vehicle is equipped with a 7-pin trailer plug rated at 30A per pole, which conveys power to a three-way fridge and 200Ah worth of house batteries. A Redarc Voltage Sensitive Relay (VSR) isolates the starting battery from the house batteries when the engine is off.

With the engine off, the fridge draws 14A from the house batteries. Once the engine starts and the vehicle electrical system voltage rises above 13.2V, the VSR latches, connecting the starter battery to the house batteries.

This is where things go south. The Isuzu's alternator gives the charging battery a short burst of charge on start-up then effectively switches off, allowing the caravan house batteries to back-feed the vehicle while also powering the fridge.

The battery voltage sits around 12.5V, just high enough to hold in the VSR, while silently flattening the very expensive house batteries and leaving little power at the next destination.

In the case of the Isuzu, I found turning the headlights on forces the alternator to hold the voltage around 14.4V, to correctly charge the house batteries and power the fridge. How many people are unknowingly getting caught out by this insanely deficient automotive design practice?

Our Toyota Hilux fitted with beacons and radios has needed an excessive number of battery replacements due to this inadequate charging pattern. The highest charging voltage I measured is 13.5V so the batteries never see a full charge. Very, very poor.

Dale Sills,
Bunbury, WA.

Response: modern vehicles which eschew the old-fashioned constant battery charging method seem to use a variety of different methods to control the alternator. In many cases (especially in vehicles more than a few years old), it is a very simple one-wire control system where the ECU can disable the alternator output.

Often, the alternator will have a 3-pin plug and it seems to be typically the middle pin which is used to shut down the alternator output.

This pin may also be used to indicate that the alternator is working. It appears that the most common control scheme is that this pin is driven high to enable the alternator and it will sink enough current when the alternator is working normally to light a lamp.

You would need to check the service manual for your vehicle but if this is the case, you could potentially cut that wire and insert an SPDT switch, which in one position re-joins the two halves of the wire for normal operation and in the other position, connects the control terminal to the battery positive via a small fuse.

That switch would then allow you to force the alternator to charge the battery without having to switch on the headlights.

In vehicles manufactured within the last few years, it's likely that the ECU actually communicates with the regulator in the alternator using some sort of digital protocol and is able to program it to produce a particular voltage as well as shut its output down when not needed. Such a scheme would be much more difficult to defeat.

Note, that you can also have the problem in some vehicles that the ECU's alternator control logic is based on the output of a sensor attached to the battery positive terminal, which measures the current flowing into and out of the battery.

If you connect any accessories directly to the battery terminal, they will bypass this sensor and that would interfere with the alternator regulator control logic.

As we've said in the past, it seems likely that the minuscule fuel savings from this fancy alternator control logic are outweighed by the cost of having to replace the battery more often.

Trouble finding Arduino USB I/O files

I went to the link you gave for the ioduino project, to turn an Arduino into a USB I/O device, which was published in the Ask SILICON CHIP section of the June 2018 issue (page 104). I clicked the link which took me to **https://code.google.com/archive/p/ioduino** but then I got a "404 Not Found" error.

Jack,
Bendigo, Vic.

Response: it must have been a temporary glitch at Google since we just checked that link and it loaded fine. It brought up a page which text reading "To get started, see the guide here" (where the word "here" is a link) and clicking that link gives a helpful document explaining what the ioduino project is and how to use it.

There is a Download link at the left-hand side of the page which brings up two zip files to download, one for version 1.0 of the software and one for version 1.1.

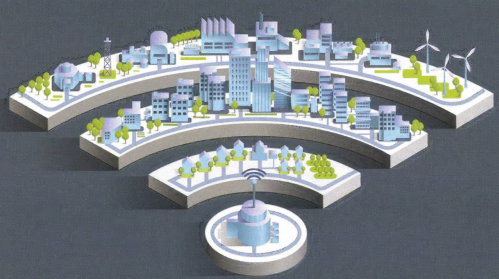
Installing DAB+ radios in cars etc

Would you consider doing an article about mobile DAB+ radio in Australia? For example, what aerials are available, whether you can build your own, how to mount them, whether a whip antenna can be used and if so what material to make it from etc?

David Maxwell,
Hillside, Vic.

Response: all portable DAB+ radios have their own in-built antenna, either via the headphone wiring or a telescopic whip antenna. There is no point in making one.

If you want much better DAB+ reception from a portable receiver used at home, you can build our 5-element DAB+ Yagi antenna featured in the



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The Internet of Things

The Internet of Things (IoT) is the growing network of physical devices, vehicles, home appliances, and other items able to connect and exchange data through internet connectivity so they can be remotely monitored and controlled.

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Bugs found (and fixed) in ADF4351 PLL code

I previously wrote to you regarding some strange behaviour I was experiencing with an ADF4351 digitally controlled oscillator module.

I used instructions from your El Cheapo Modules article (May 2018; siliconchip.com.au/Article/11073) to program the module but the output frequency was not always correct and I was getting some other spurious signals in the output.

I have now spent some time looking at the Micromite code you provided and I think I have found the source of the problem. The line in the BASIC file which reads:

```
INTA = (OutFreq * RFODiv) /
  FPFD
```

should instead read:

```
INTA = FIX( (OutFreq * RFODiv)
  / FPFD )
```

The addition of the FIX() function ensures that the INTA variable contains an integer (ie, whole number) and this is necessary for the following calculations to have the correct results. I also changed the line which reads:

```
ADFReg[2] = &H4E42
```

to read:

```
ADFReg[2] = &H60004E42
```

This enables the "low spurious" option. These two changes in combination have totally solved the problems I was having.

Another interesting item I have added to my generator is a small attenuator module (0-61dB) from sv1afn in Greece: www.sv1afn.com/rfattenuator.html

While not particularly cheap, I have purchased two sets of the attenuators and control modules and recommend them if someone wants to add a variable output option to the generator.

When I have time, I plan to add switching so that the rotary encoder used with the attenuator module can also be used for quick adjustments of the last two digits of the output frequency.

Many thanks for the basic ideas and hard work getting the code to where you had it. Much appreciated. I now have a very useful signal generator that is easy to use, low cost and it really works. Thanks, Jim and Silicon Chip.

Colin Schulz,
Mount Waverley, Vic.

Jim responds: Many thanks for your careful work in finding the errors/omissions in my code that were causing the problems you were having, and also for your courtesy in letting us know of how you found and fixed them. We have updated the software download on our website to incorporate your changes.

November 2015 issue: siliconchip.com.au/Article/9394

That article also had instructions on how to connect it to a DAB+ portable by fitting it with a coax socket for the antenna cable.

A point to remember is that DAB+ is only available in the capital cities and a few regional centres.

New mode wanted for the Sound Effects Module

The Super Digital Sound Effects Module caught my attention when I first saw the magazine because I would like a better voice for my robot and the currently planned speech module uses an obsolete speech chip (SP0256-AL2).

This was a great chip for its time with no limit to the library of messages that could be generated. However, its speech quality is not wonderful and I have been reluctant to proceed with the installation.

When I saw the new module design I thought this would be a great replacement since the SD card can store a very large number of messages and the speech quality will be far superior to the SP0256.

However, after reading the article, I realised that I could only use it to select playback of seven unique messages.

Just the same, I have ordered a kit of parts for a trial. Audio has never been one of my interests and this module will make for a nice experimental platform.

I did check to see if it was possible to implement a serial interface using the existing trigger inputs and I found that three of the trigger pins can be reassigned as either RX or TX.

Using two other lines for a BUSY output and a STOP input, a simple serial interface can be implemented. However, I have no idea if there is any program space available for the extra routines.

George Ramsay,
Holland Park, Qld.

Response: the idea of providing a serial port that could be used to send commands to play back specific file names from the SD card is a good one. We will look into the possibility of adding this mode into a future version of the software. There should be sufficient flash space available to allow this.

DC boost circuits can be useful

I have just received the August issue of Silicon Chip and on reading the Editorial Viewpoint have learned of Leo's retirement. Does this mean we are not going to see any more of your interesting articles? Yes, you have been controversial at times, however, the boat needs rocking from time to time.

My view is in terms of energy and saving the planet, mankind has always found ways to forge ahead bearing in mind the obstacles and compromises.

I was interested to note the submission in Circuit Notebook by Petre Petrov for a dual rail boost converter supply providing ±15V DC from a +5V DC supply.

Recently, I needed to reduce the number of boxes on my desk used to switch receiving antennas. I wanted to control them from one purpose-built unit which can switch to any one of six possible antennas via an external relay box.

The problem was that one antenna (a wideband amplified whip) needed a 24V DC supply via the coax feed to the amplifier at the base of the whip but the remote control box ran off an internal 12V DC supply. I had made provision for feeding 12V DC via the coax centre conductor to one of the six possible antennas. However, now I needed 24V there too.

I thought I'd have a look on eBay, bearing in mind recent comments and Jim Rowe's articles in the magazine about cheap modules from China. What I found was a number of sellers of variable output "boost converters" at ridiculously low prices with free postage, so I ordered two for just over $10 and they were delivered in less than two weeks!

I connected one to my 13.8V DC bench supply and adjusted the converter's output to 24V. I then used a portable radio to check for radiated emissions, and there were some and

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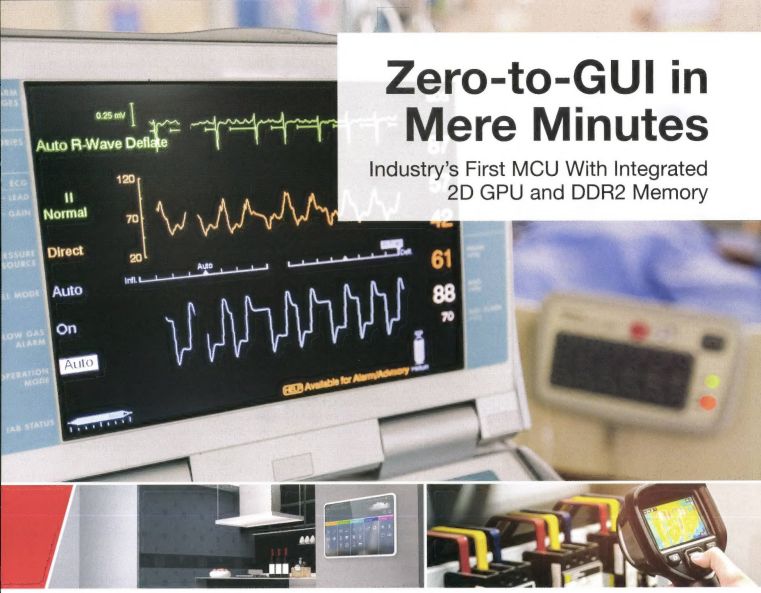

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strong! The switching frequency was specified as 400kHz, so I decided to make a small tin-plated steel enclosure to house the unit and further incorporate some filtering to remove conducted emissions.

Once installed in the remote control unit, checks were conducted using a software-defined radio (SDR) where I was able to observe the frequencies of the previously noted hash. They were now down in the noise level and were of no significance.

Richard Kerr,
Cessnock, NSW.

Response: we expect that Leo may contribute articles to the magazine from time to time (we have a number of regular contributors who do not work for us) but that is assuming he isn't busy boating or otherwise enjoying his retirement.

We sell two low-cost pre-built DC boost modules in our Online Shop, Cat SC4437 (5-28V at up to 2A) and Cat SC4438 (4-38V at up to 4A). This type of module is likely to produce strong hash so your approach of adding shielding and providing extra filtering is a good idea.

High mains voltages still a problem

In the August 2018 issue, there was a letter in Ask Silicon Chip from B. D., of Mount Hunter, NSW titled "High mains voltage causing equipment damage" (page 97). I have had the same problem. Our mains commonly swings between about 230-252VAC. This appears to have caused my set-top box to fail.

When I saw the article in the March 2011 issue of Silicon Chip on the Mains Moderator (siliconchip.com.au/Article/937), I immediately put one together. It drops the maximum mains voltage to my TV and STB by 20V and I have never looked back. It's cheap and effective insurance!

Dick Polderman,
Culcairn, NSW.

Audio tape biasing is generally misunderstood

The Philips EL3302 Compact Cassette recorder article in the July issue was another trip down memory lane for me. I have a few comments on that article.

Though I worked for many years as a recordist and dialog editor, recording on Nagras in the bush and multitracks in the studio, I have not heard "the old adage" of "a kilohertz per inch per second". In fact, if it were "two kilohertz per inch per second", it would be closer to the mark.

The typical -3dB bandwidth for open-reel tape at 3.75ips is about 8kHz; at 7.5ips it is about 16kHz. At 15ips, response runs to somewhere between 22-25kHz. 7.5ips was regarded as broadcast quality because it was flat to more than the 15kHz required for FM and TV broadcasting.

In the part about bias, there is a sentence: "This effectively blankets the tape with ultrasonic signal of greater amplitude than the signal being recorded." Actually, the bias signal only needs to be the amplitude of the line between points "d" and "g" in Fig.3 to ensure that the media is magnetised properly when the signal is low or near the zero line, to avoid crossover distortion (to match the coercivity of the magnetic media).

If the bias level is too high, the frequency response and signal-to-noise ratio suffer. If it is too low, distortion will increase significantly. That is why bias level was an important setting and on professional machines, was always calibrated to suit the tapes being used.

If the hysteresis curve was really as curved as shown in Fig.3, tape recorders would not be capable of distortion of less than 1%; it is below 0.5% on many professional recorders. The slopes should be somewhat more linear. You can see a more correct representation of the curves at: siliconchip.com.au/link/aak9

I believe the AC bias transfer diagram at www.hccc.org.uk/acbias.html is also not actually correct. The bias amplitude shown is much too great and if that was the resultant recorded signal level, the signal-to-noise level would be no better than when using a DC bias. The relative amplitudes of the input signal and bias should be swapped.

The bias level should be just enough to push the positive and negative phases of the signal past the magnetisation threshold and into the linear regions, similarly to how a DC offset is required for each phase in the output stage of a Class-AB amplifier to avoid crossover distortion.

It seems to be difficult to find a correct tape transfer diagram online, showing what bias actually does. Fig.3 at siliconchip.com.au/link/aaka is better than many, as it shows the full output

signal amplitude, but an analysis shows the transfer from the input signal can't be correct.

It again only shows the input amplitude as fully contained within the linear sections of the positive and negative phases but the output signal is twice that amplitude. I have seen a correct transfer diagram, but don't recall where.

In audio archives these days, we use high sampling rates to capture the remnant bias signal from old tapes and use it as a reference to correct tape speed aberrations from early field recorders.

Many of the early tape recorders used bias frequencies of 30-40kHz or so, which is now easily captured. Professional recorders from the 1960s on used a bias of 100kHz or more, which is beyond the capability of most audio analog-to-digital converters.

By the way, I believe cassettes were also widely used by Ayatollah Khomeini during the Iranian Revolution, to swing popular opinion prior to his return. This is mentioned in Wikipedia. See: siliconchip.com.au/link/aakb

It seems that cassettes played a notable role in more than one revolution!

Noel Bachelor,
Senior Recording Engineer and GRN Global Studio Coordinator,
Seven Hills, NSW.

Vintage Radio article on Privat-Ear enjoyed

I would like to thank your magazine for presenting the wonderful article on the Privat-Ear radio written by Ian Batty (November 2017; siliconchip.com.au/Article/10880). It is the most comprehensive write-up of this rare radio I have ever seen in any publication, ever.

I had one for a short time and was at a standstill in getting the little codger to work. Even though it would be a display item in my modest collection of radios, I like all my little sets to work. Mr Batty's wordsmithing brought me to the brink of success in that I was able to understand how the radio was supposed to work so troubleshooting became obvious.

The final success came when SILICON CHIP forwarded my query concerning the specs of the audio choke to the author who responded with the information I needed. I dug through my junk boxes in search of a small audio inductor of around 700Ω.

I found a transformer in an old Zenith three transistor hearing aid that measured close to 500Ω on one side and was very close to the dimensions of the bad choke. I clipped the leads from the transformer I did not need and slightly enlarged the opening in the plastic circuit board with my soldering iron, made the connections, and Bob's your Uncle!

Two local stations came booming into the earpiece with three 9V batteries in series for the HT. Thank you for the fine article!

Sloane Freeman,
Newton, NC, USA.

Differences in Ethernet cabling requirements

In response to the letter by Brian Wilson in the Mailbag section of the June 2018 issue ("Gigabit Networks require Quality Cabling"), from the information Brian supplied it sounds as if his 100Mb/s network was running, prior to his upgrade, in half-duplex mode if only two pairs were connected.

From memory, I think that the 10Mb/s standard was only half-duplex and required only two pairs and the upgrade from 10 to 100Mb/s required re-cabling. Unless upgrading the actual cable quality from Cat5 to Cat6e for example, no re-cabling is required to move from 100Mb/s to 1000Mb/s.

David Dorling
Buderim, Qld

Response: that isn't quite right. 10BASE-T requires Cat3 cabling, 100BASE-TX requires Cat5 cabling and 1000BASE-T requires Cat5e or Cat6 cable.

So in both upgrade cases (from 10Mbit to 100Mbit or 100Mbit to 1000Mbit), it may be necessary to upgrade the cable, depending on whether you already had a cable built to a higher specification than was necessary.

Both 10BASE-T and 100BASE-TX operate over two of the four pairs, leaving the other two available for telephone lines. 1000BASE-T uses all four pairs.

It would definitely be possible to have fully working 100BASE-TX over a cable with at least one improperly terminated wire, which would then fail to operate in 1000BASE-T mode (the device would likely drop back to 100Mbit automatically).

You may be able to get away with using worse-than-specified cables

(1000BASE-T working on Cat3 cable is not unheard of) if the runs are short enough. But we don't recommend it as it may result in data corruption and it may not work consistently with different devices.

Computer audio connections can suffer from Earth loops

While Apple computers are capable of superb quality sound, many recent models have eliminated sound input connections and optical fibre (TOSLINK) connections. The humble 3.5mm headphone jack has already disappeared from the iPhone and it may disappear from future iMacs.

I was unpleasantly surprised to find that connecting the headphone jack from my iMac or Mac Mini to an amplifier resulted in low but annoying levels of hum and a high-pitched whine which was obvious during quiet passages, and between tracks. This is not supposed to happen, as the internal DAC is said to be of very high quality.

My old Mac Mini (mid-2010) was one of the last to retain optical sound connections. Connecting TOSLINK cables to external analog-to-digital and digital-to-analog converters resulted in superb sound emerging from total silence.

My 27-inch iMac (late 2015 model) does not have TOSLINK connectors. An alternative would be to use the inexpensive Griffin USB iMic DA/AD converter, but I was disappointed to find that it had exactly the same problem. The iMic has a good reputation, so what was the cause?

Finally, the penny dropped. Could the problem be due to Earth loops? Installing a stereo isolation transformer (available from Altronics) between the iMic and the amplifier immediately fixed it. Perfect sound emerged from a background of total silence. Applying the same solution to the headphone output also gave perfect results.

Stray AC currents often reveal themselves when audio devices are connected through multiple earth points that include both power cords and coaxial cables.

Moreover, we live in an environment with a significant "background" of hash from switching power supplies in computers and LED lighting. Hold an AM radio close to a computer and you will see what I mean.

The solution was fairly simple, inexpensive and rewarding – high-quality digital sound with virtually zero background noise. Perhaps other readers have had similar problems.

James Goding,
Princes Hill, Vic.

Response: this is absolutely a problem and it can also happen with digital audio over coax cables (S/PDIF).

Any time that you have a ground connection between two Earthed devices, especially when one is a computer or they are plugged into different power outlets, you can get hum injection into the audio signal. The high-pitched whine you noticed is probably related to the computer's switchmode power supply.

While you can solve this with a transformer, and Altronics do sell some good-quality audio coupling transformers, these will inevitably introduce some distortion.

We suggest that the best solution is to use a USB DAC with an optical output to a TOSLINK cable which then runs to a good quality DAC near your amplifier.

We have used this type of configuration on many computers with great results. Our CLASSiC DAC design (February-May 2013; siliconchip.com.au/Series/63) works particularly well in this role.

More information about seismograph responses

I was perhaps remiss in omitting the phrase "operating below its corner frequency" when claiming the equivalence of high-pass filtering and differentiation.

I assumed this was self-evident as above its corner frequency, a high-pass filter has negligible effect.

Of course, traditional seismographs are "affected by both displacement and acceleration", both are aspects of the same phenomenon. The question is not what affects them but the character of their response.

The displacement of a pendulum excited by a forcing waveform having a frequency above the pendulum's own resonant frequency is proportional to the displacement of that waveform, for frequencies below resonance its displacement is proportional to that waveform's velocity.

Of course, the transition is gradual, for an octave or so each side of resonance the response is a confusing mixture. Traditional seismographs are designed so that their natural resonance is well below the lowest frequency of interest and thus respond to displacement. There is no scenario in which the displacement of a pendulum is proportional to the forcing waveform's acceleration.

It is worth noting that many vibration transducers, such as those used for the higher frequencies found in machinery monitoring, are designed to produce a response proportional to velocity for frequencies above resonance (and acceleration below) using a magnet and coil system (the principle of which was discovered by Michael Faraday).

Many traditional seismometers already include a magnet and conductive vane for damping their resonance so could easily have been built to give a velocity response, but it is significant that displacement continues to be the standard method for characterising earthquakes.

Tony Ellis,
Porirua, New Zealand.

Reasons why Neutral and Earth are kept separate

This letter is in reply to Ray Smith of Hoppers Crossing in the Mailbag section of the August 2018 issue, where he says he cannot understand why there is an interconnection between the Neutral and Earth bars that can be broken.

One example of where Neutral and Earth need to be kept separate is where you have a sub-board which is wired back to an RCD-protected circuit on the main board. After an RCD (residual-current device or "safety switch"), the Neutral and Earth wiring needs to be kept separate. Otherwise, the RCD will be subject to false tripping.

Many people believe that Neutral and Earth are basically the same but they are different from the perspective of an RCD. So there are times when they would not be connected directly together.

D. R. Haddock,
Bethania, Qld.

Separate Earth bar with Neutral link is required

Having read Ray Smith's letter in the Mailbag section of the August issue ("Neutral and Earth should be connected to same bus bar"), I suggest that Ray Smith immediately arranges for the electrical installation in his home and shed to be checked by a competent

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and licensed electrician. As described, the installation is dangerously unsafe and potentially deadly.

The Earth bar and Neutral bar should be connected by the "MEN Link", which is a short length of suitably sized Earth wire that is "bonded" to both bars. Bonded means that the cable is terminated in the terminal/bar with two screws.

All Earth wires must be bonded, whether at the terminal bar or at the outlet (usually with a BP connector). Thus, the Earth bar will be the bar with the two screws per terminal.

The MEN link is there so that it can be temporarily removed when required for specific testing of the installation with separate Earth and Neutral networks without unduly disturbing the wires terminated at the bars.

The photo accompanying the letter showed the Neutral bar in the subboard with the incoming neutral connected to a two screw terminal (correct), the neutrals of the out-going circuits connected (correct) and an Earth wire connected to a two screw terminal on the neutral bar.

Is this the incoming Earth wire? If so, then where are the outgoing Earth wires terminated? Or is this the MEN link? Where is the Earth bar, where the incoming Earth wire should be terminated as well as the out-going Earth wires?

Mr Smith managed to trip an RCD that he didn't know existed. Before working on wiring, it's always a good idea to check the voltage between Neutral and Earth or some metal definitely in close contact with the ground.

This could save you from a potentially lethal situation where a fault has caused the Neutral wiring to be at 230VAC potential. You definitely should not assume that touching a Neutral wire is safe!

The RCD most likely tripped because there was a significant potential difference between Neutral and Earth. If this was much higher, the current through his body when he completed the circuit from Neutral to Earth could have been fatal, even with the RCD tripping. RCDs generally do their job well but if my life was fully dependent on them functioning correctly every time, I would ensure my safety by additional means.

This potential difference was likely present because Neutral was not bonded to Earth at the sub-board. Every sub-board should have an Earth stake to the ground which is bonded via an Earth wire to the Earth terminal. This Earth stake references or ties the Neutral and thus the whole sub-board circuit to ground potential at that point, ie, in this case, the shed.

It seems that the Neutral wiring in this shed was floating (electrically) at some indeterminate voltage that was at a difference to the incoming Neutral.

Since we don't know where or how the Earth wiring is terminated, as there does not appear to be an Earth bar in the fuse box, this could well be due to a wiring fault.

Trevor Krause (Retired Electrician), Gympie, Qld.

Another dodgy power board fails

Shortly after reading the correspondence about poor quality power boards (July 2018, page 4) I encountered an example.

Two of the four outlets on the brand-name board in question did not accept the plug Earth pins. I used a saw to cut it open (see photograph below). I agree that the problem is sub-standard metallurgy, with soft brass being used rather than hard-drawn spring brass.

While the board has an Australian brand name on it, like most electrical equipment, it is likely to have originated overseas. A faulty Earth connection could be lethal. I am not impressed.

James Goding, Princes Hill, Vic.

Varying u-blox GPS reference frequency

Congratulations to Jim Rowe on his excellent articles covering El Cheapo Modules. With regard to the u-blox Neo-7M GPS Receiver (October 2016; siliconchip.com.au/Article/10827), I was wondering if you have done any research into the configurable PPS output. As you indicated, while it defaults to producing 1Hz pulses, the PPS timer on this module (and later versions) has a configurable range from 0.25Hz to 10MHz.

I have experimented with the Neo-7N model (approximately US$7.50 from eBay), which has a TCXO in place of the crystal used in the -7M model.

The "u-Center" application, downloaded from the u-blox website, allows you to set the PPS output (called Timepulse5) to any frequency from 1Hz up to about 16MHz (when jitter becomes excessive). When checked against a Rubidium clocked frequency counter, the output is accurate to the Hz, albeit with the occasional jump of 1Hz!

Separate frequency settings are available for the NO-FIX and FIX conditions. The accuracy of the NO-FIX setting is very good, even when cold. Apparently, jitter is minimal for frequencies which divide evenly into 48MHz.

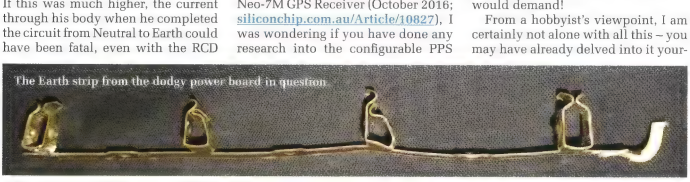
I have used this module as a substitute for the crystal oscillator of the PIC16F88 processor of John Clarke's Compact 8-Digit Frequency Meter (August 2016; siliconchip.com.au/Article/10037). The PPS output is set to 4MHz (both for NO-FIX and FIX conditions) and drives the external clock input of the PIC16F88 directly.

Of course, an adjustment needed to be made to the source code/HEX file to enable external clock operation. From just seconds after switch-on, the counter maintains very close accuracy until GPS FIX occurs.

At that point, the display, in 1Hz resolution mode, indicates and maintains a rock-solid 10.000000MHz when fed from my Rubidium frequency standard.

I have also designed a simple controller for using the Neo-7N as a signal generator operating over the above frequency range with GPS accuracy. It works very well, even though the output waveform is not what the purist would demand!

From a hobbyist's viewpoint, I am certainly not alone with all this – you may have already delved into it your-



The Earth strip from the dodgy power board in question.

self and there are a number of web and YouTube references on the same subject. The documentation from u-blox is an absolute necessity especially for understanding the specialised command formats for driving these modules directly.

I thought this may be of interest to your readers. The following websites are very helpful if you want to reprogram one of these GPS modules:

www.qsl.net/pa2ohh/17gps.htm
http://youtu.be/lbns-FvpzK4

David Padgett,
Ringwood, Vic.

Jim responds: thanks for your very informative letter and also for your kind words regarding the El Cheapo Modules articles. You certainly seem to have worked out ways of making the Neo-7N module jump through hoops to generate many different reference frequencies, so please accept my congratulations.

Adding LED frequency displays to old equipment

I have started noticing 6-digit and 8-digit LED frequency display modules on sale from Chinese vendors. They seem to use a PIC16F648A to drive the display. These could be the subject of an interesting article in the magazine.

I have added such modules to test equipment with frequency outputs, to save having to bring out and connect up a separate frequency counter.

One example is on a Leader LSG11, a valve-based signal generator – a mix of old and new technology. Adding the display made it easier to see exactly what frequency it is producing; it's easier and more accurate than reading the analog scale.

If such an article is written, perhaps it could explain how to change the software to prevent the display blanking when the frequency is below 100kHz. For my applications, I would like to remove the blanking completely or at least reduce it to 1kHz.

Keep producing an interesting magazine. I enjoy every issue of SILICON CHIP (and Radio Waves from the HRSA).

John Murphy,
Glen Waverley, Vic.

Agreement with Editorial viewpoint

In my opinion, the editorial in the September 2017 issue of SILICON CHIP on the adoption of electric vehicles was well thought out. Unfortunately, the people who make these decisions make them on the advice given by people with a drum to beat. Keep up with the good work. The Editorial and Letters to the Editor are the first things I read.

Ray Cottier,
via email.

Nicholas responds: that Editorial has proven somewhat controversial but nothing has happened since then to change my opinion. In fact, call me cynical but I think that most of the groups announcing that they will ban combustion engine vehicles way into the future have no intention of actually doing it.

They know that they can make the announcement to a fawning press but most will not be in office when the time comes and so will not be blamed when it doesn't happen because it's far too impractical.

Electric vehicles may well improve to the point of widespread adoption but like virtually all technological shifts, that will be driven by the marketplace, not politicians. And it will happen if and when the technology is mature which may or may not be as soon as is being predicted.

Rangehood repair was manufacturer's responsibility

I must congratulate you for your 30th anniversary. During the same time you have been publishing, many companies large and small (billion dollar companies in fact) have come and gone but you have soldiered on, or should I say "soldered on"? Well done!

In the age of the IoT I also think that the relevance in today's world of your publication is greater than it has ever been in the last 15 years. Given the variety of cheap single-chip computers, there is hope we can breed a generation of electronics enthusiasts that will drive the next generation's economy.

I am a part-time reader of your magazine but since I received a subscription as a Christmas gift from my children, I have enjoyed every edition. It has rekindled my interested in electronics that was lit by an electronics subject I did in high school in 1976 in Canada, when I built my first superhet receiver from valves, no less!

In the last five years, my son and I purchased an old 1930s Lekmek cabinet radio and brought it back to life. It still sits with pride in the sitting room and fills the room with warm tones that only a valve amplifier can produce. It was a great father/son bonding exercise in the garage over a number of weekends that I can recommend to any dad.

The reason I write though, is about Dave Thompson's article about fixing his rangehood in the November 2017 issue. He is obviously a master technician; I am amazed at the things he tackles – in many cases, people would just replace it but Dave fixes it! Dave made a comment that the rangehood failed "a few weeks after the (rather short) warranty ended".

This is too true in many cases but the law is in fact on the side of the consumer here and manufacturer warranties are really not that valid. The consumer protection law (see the ACCC web site at siliconchip.com.au/link/aakw) states that a product must be fit for purpose.

If one buys a rangehood (or fridge, or car...) they don't need to care much about the 12-month warranty. I would expect that a rangehood would last maybe five years, certainly longer than 12 months. If it fails before five years, I would contact the manufacturer and ask for a replacement (which I have done successfully in the past).

If they refuse because it's "out of warranty", then your readers should remind the company of their obligations under the ACCC Act and, if they refuse to replace, then you can make a complaint to the ACCC and have them chase the manufacturer.

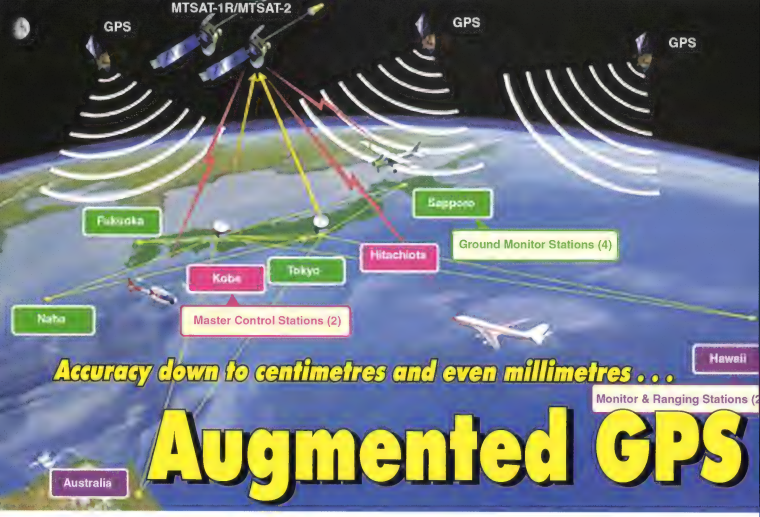
Keep all your records including the conversations you have had with the manufacturer.

If worst comes to worst, you can take them to small claims court to seek compensation, which does not cost that much. In the majority of cases the ACCC will get a correct result (a replacement) and if you ever need to send them a notice to appear in court, they will just give you a replacement because their lawyers will tell them they don't have a legal leg to stand on.

I think this is an important message to the Australian public because they put up with products that are substandard. We should hold all companies to account for their products so that we actually get products that last, like my 90 year old Lekmek AM receiver!

Paul Merrill,
Sydney, NSW.

Comment: while Dave Thompson is a Kiwi, New Zealand has similar consumer protections to Australia. SC



Accuracy down to centimetres and even millimetres . . .

Augmented GPS

Everyone knows how effective – and accurate – today's Global Navigation Satellite Systems (GNSS) are. But it wasn't always so – and even the ~5m typical accuracy of a modern GPS is nowhere near good enough for many of today's more demanding tasks, such as landing an aircraft, controlling driverless cars or monitoring earth movements and tides. That requires a whole new approach, called "augmenation".

The typical GPS navigation error is actually amazingly good if you consider how large the Earth is and how far above you the satellites are orbiting (even though they are in low-earth orbit). But clearly, it could be a lot better.

Many applications require much better accuracy, in some cases down to the centimetre level. That includes precision farming, aircraft navigation, marine navigation, self-driving cars, land surveying, construction, drone navigation, augmented reality, animal tracking and military uses.

GNSS devices (of which GPS is just one) are less accurate than they might otherwise be due to introduced errors.

Error sources can be categorised into two types: **"user equivalent range errors"**, which relate to timing and path differences in the radio signals received from the GNSS satellites and **"dilution of precision"**, which relate to a non-ideal arrangement of satellites in the sky – the receiver cannot "see" enough satellites to establish or maintain reliable readings.

Examples of user equivalent range errors, in order of decreasing severity, are:

- drift of the satellite clocks,
- deflection and delay of the satellite signals in the ionosphere,
- instability in the clock of the receiving device,
- uncertainty of the satellite orbit,
- signal delay in the lower atmosphere which also depends on the angle the satellite signals subtends to the atmosphere and
- multipath errors of the satellite signals in mountainous, heavily wooded or urban terrain.

Some of these error sources can be partially corrected by the GNSS system but others cannot.

So how can higher accuracy be achieved?

Augmentation to correct errors

GNSS augmentation involves gathering information about positioning errors, such as those due to ionospheric delay,

by Dr David Maddison

at various locations and times. This correction information can then be transmitted to GNSS receivers where it is combined with the normal positioning information to produce a more accurate "fix".

Perhaps the simplest method for calculating the position error is to have a ground-based station with an accurately known position, constantly receiving and decoding GNSS signals.

The difference between the calculated position fix and known position is the error term. Other receivers nearby are likely to have a similar error term, as many of the error sources will be the same.

Therefore, by transmitting the known error term from the fixed receiver to the nearby mobile receivers, they can correct their own position fixes, to get a much more accurate position. GNSS systems currently in use include GPS (US), Galileo (EU), GLONASS (Russia) and BeiDou (China).

An augmentation system may be satellite-based, in which case it is known as a Satellite-Based Augmentation System (SBAS). Or error correction information may be transmitted from ground stations, in which case it is known as a Ground-Based Augmentation System (GBAS). SBAS systems operate over wide areas such as entire countries while GBAS have more local coverage.

There are a number of SBAS systems now in use, most with non-global coverage. These include:

- **Wide Area Augmentation System** (WAAS; USA)
- **European Geostationary Navigation Overlay Service** (EGNOS; EU)
- **Multi-functional Satellite Augmentation System** (MSAS; Japan)
- **Quasi-Zenith Satellite System** (QZSS; Japan)
- **GPS Aided GEO Augmented Navigation** (GAGAN; India)
- **System for Differential Corrections and Monitoring** (SDCM; Russia)
- **Wide Area GPS Enhancement** (WAGE; US Military)
- **StarFire navigation system** (commercially operated by John Deere)
- **C-Nav Positioning Solutions** (commercially operated by Oceaneering)
- **Starfix DGPS System** and **OmniSTAR system** (both commercially operated by Fugro)

The non-commercial SBAS augmentation signals can be received by nearly all modern GPS and other GNSS receivers, and starting this year, by some phone models (see Fig.16). The correction signals are transmitted by

The navigational paradox: more accuracy is not always better!

The navigational paradox states that with greater navigational precision, the likelihood of ships, aircraft or land vehicles occupying exactly the same space on designated routes increases and so does the risk of collision.

Solutions to this problem include requiring different vehicles on the same route to incorporate slight deviations from the nominal route, such as being offset from the route by a certain distance, and improved traffic management and collision avoidance systems.

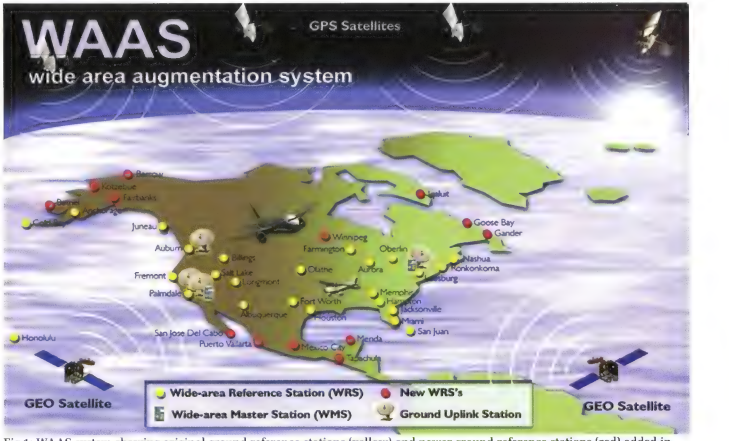


Fig.1: WAAS system showing original ground reference stations (yellow) and newer ground reference stations (red) added in Mexico, Canada and Alaska in 2008 to extend service area. Correction signals are generated by the ground stations, sent to the ground uplink stations and then sent to geostationary satellites where they are retransmitted to WAAS-enabled GNSS receivers.

geostationary satellites (the positioning satellites are in low-Earth orbit).

SBAS signals for GPS are transmitted on either the L1 frequency bands centred at 1575.42MHz or in some cases, the L5 band centred at 1176.45MHz which is a protected "safety of life" aviation band. These are the same frequency bands on which navigational data from the GPS satellites is received.

In contrast to SBAS signals, receiving GBAS signals typically requires specialised equipment.

Note that some SBAS systems are certified for aviation use by the International Civil Aviation Organisation (ICAO) and meet certain standards. Non-aviation use SBAS systems may use propriety technology which cannot be certified under ICAO standards.

New Australian system

In the 2018 Federal Budget, $225 million was allocated over four years to Geoscience Australia for the development of an Australian GNSS augmentation system.

This is intended to cover continental Australia as well as the Cocos Islands, Christmas Island and the Australian Antarctic Territories.

Separately, Geoscience Australia is also running a two-year project in conjunction with Land Information New Zealand (LINZ), to be completed in January 2019, to test two positioning technologies: next-generation SBAS and Precise Point Positioning (PPP).

Note that there are already some commercial SBAS services available in Australia (eg, John Deere's StarFire, described below).

Like other SBAS systems, the new Australian system will take into account Australia's continental drift (to the north-east at 7cm per year) which has put Australia's official map grid out of kilter with its true position on the Earth's surface (see panel for more details).

Geoscience Australia is assessing the suitability of SBAS technology for agriculture, aviation, construction, maritime,

A history of GNSS augmentation

In the early days of GPS (which was developed by the US military but made available to civilian users worldwide), there was a concern that enemies of the USA would use GPS to guide missiles to targets within the USA or their allies.

This lead to a deliberate signal degradation being imposed on the GPS service known as "Selective Availability" (SA), which made civilian GPS much less accurate than the military version.

Originally, it was thought that the uncertainty in position would be about 100m but with better receiver designs, it became closer to 20-30m. This still wasn't accurate enough for some users and Differential GPS or DGPS was developed as the US military insisted SA must remain, despite a lot of pressure from other US Government agencies as well as civilian users.

It was eventually realised that the offset in the deliberately degraded SA signal was relatively constant and varied slowly, so if there was a land-based transmitter at a precisely known location, it could calculate the offset and transmit it to a suitable GPS receiver which would then apply the offset to the calculated position.

That, along with measurements due to ionospheric delays, also transmitted by the base station to the receiver, enabled an accuracy of 5m even with SA enabled, as long as the receiver was suitably close to a DGPS transmitter site.

As it wasn't easy to provide DGPS transmitters at all the sites required (as the range was tens of kilometres), the US FAA started investigating transmitting correction signals by satellite, which lead to the development of the Wide Area Augmentation System (WAAS) and eventually other similar satellite-based augmentation systems (SBAS) which are discussed in this article. By the mid-1990s, it was apparent that DGPS had rendered SA of little value, which led to a decision to permanently turn it off on May 2nd, 2000.

There are several types of DGNSS (Differential GNSS). Classical DGNSS, using an accurately surveyed reference station, can achieve position accuracies of 1m at distances up to tens of kilometres from the station.

RTK (Real Time Kinematic) corrections use carrier phase measurements from the GPS satellites to achieve centimetre accuracy as long as a reference station is close to the receiver, preferably within 15km. WARTK (Wide Area RTK) allows for stations to be up to 500-900km distant.

SBAS as described in this article, of which WAAS (USA) was the first of its kind, are gradually replacing those DGNSS systems which only work over short distances (ie, Ground Based Augmentation Systems or GBAS).

SBAS works over continental areas and eventually should be available globally. These systems can be thought of as wide-area DGNSS systems.

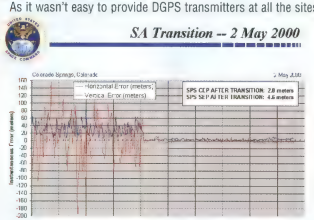


Fig.2: error estimates for civilian users of GPS hours before and after Selective Availability was permanently turned off.

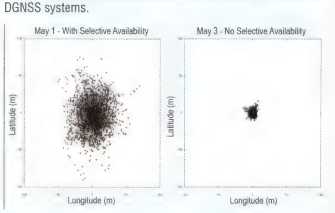


Fig.3: ground station showing 24 hours of data and scatter of positional data on May 1st (left) and May 3rd (right) before and after Selective Availability (SA) was turned off. With SA 95% of the points fell within 45m and with it switched off 95% fell within 6.3m.

mining, rail, road, utilities and consumer use.

According to Geoscience Australia, the specific elements of the test system are:

- An L-Band satellite transmitter operated by Inmarsa
- The operation of a satellite uplink at Uralla NSW by Lockheed Martin
- A positioning correction service operated by GMV and Geoscience Australia
- A GNSS ground tracking infrastructure operated by Geoscience Australia and LINZ
- A testing program partnership between Geoscience Australia and FrontierSI.
- LINZ overseeing the SBAS test program in New Zealand

Testing has so far confirmed the expected accuracies for both second generation SBAS and PPP.

Specific technologies being tested are:

- Single frequency L1 "legacy" SBAS, equivalent to current WAAS and EGNOS systems, to improve position accuracy to one metre or less
- Next-generation SBAS L1/L5 dual-frequency multi-constellation (DFMC) involving GPS and Galileo with the correction signal transmitted on L5 (see Fig.17).
- PPP service using GPS and Galileo with correction data transmitted on L1 and L5 and an expected accuracy of 10cm or better

Most GPS users in Australia should be able to see improvements from the "legacy" SBAS system right now but it is not currently certified for "safety of life" applications. Many GPS devices will use this data without any intervention but on my handheld GPS, I had to enable the option to use WAAS/EGNOS (see Fig.19).

Despite the confusing names (WAAS/EGNOS are not available in Australia), the option enables SBAS, not necessarily those two systems in particular. More specialised equipment will be required to use next-generation SBAS and PPP.

Overview of existing SBAS systems

WAAS – USA

The Wide Area Augmentation System (see Fig.1) was officially developed to improve the accuracy of GPS fixes used by aircraft. Testing of the system started in 1999 and it was commissioned in 2003. Ground reference stations measure inaccuracies in the GPS signals and send the corrections to master ground stations.

These send the corrections on to the WAAS satellites every five seconds (or less) and they then transmit the signals to WAAS-enabled receivers.

The WAAS specification requires a position error of no more than 7.6 metres both horizontally and vertically 95% of the time but typical accuracy figures achieved throughout the contiguous US and most parts of Alaska are 1.0 metre horizontally and 1.5 metres vertically.

Since this is primarily an air navigation system, system integrity is of critical importance and if significant errors are detected in the GPS or WAAS system, a warning signal must be sent to users within 6.2 seconds to indicate that the navigational data is invalid. The system must also have a high level of availability, equivalent to downtime of no more than five minutes per year.

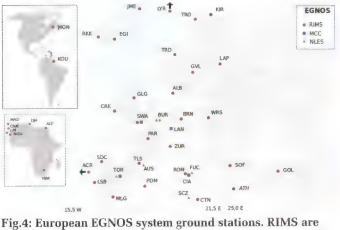


Fig.4: European EGNOS system ground stations. RIMS are Ranging & Integrity Monitoring Stations that receive signals from US GPS satellites, MCC are Mission Control Centres for data processing and calculation of correction; and NLES are Navigation Land Earth Stations where data is sent to geostationary satellites for retransmission to end users.

EGNOS – EU

The European Geostationary Navigation Overlay Service was developed by the European Space Agency and the European Organisation for the Safety of Air Navigation (EUROCONTROL) which started operations in 2005. It involves 40 Ranging and Integrity Monitoring Stations (RIMS) ground stations, four Mission Control Centres (MCC), six Navigation Land Earth Stations (NLES) and uses three geostationary satellites (see Fig.4).

It provides correction data for the GPS (US), GLONASS (Russian Federation) and Galileo (European Union) GNSS systems. The system is designed to provide no less than seven metres horizontal accuracy but in practice, it is around one to two metres (see Fig.5). Work is currently underway to extend EGNOS coverage to southern Africa.

EGNOS is primarily of value to aviation users as, due to the low angle of the geostationary EGNOS satellites over

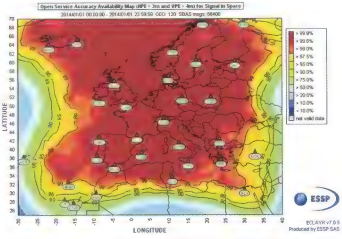


Fig.5: present coverage area of EGNOS showing horizontal and vertical position accuracy (HPE and VPE) at less than 3m and 4m respectively and the probability of achieving this accuracy. This data is sent out to EGNOS users and is frequently updated. In practice 1 and 2-metre accuracy is achieved.

Is special equipment required to receive SBAS signals?

Nearly every GNSS receiver made today is SBAS-enabled (for non-subscription services) and they are automatically configured to receive and use the signals with no extra hardware or software required.

You do, however, need to be within an SBAS service area.

There is also typically an accuracy difference between consumer grade GNSS receivers and professional and aerospace grade receivers.

Some mobile phones are starting to support SBAS and the first to do so use the Broadcom BCM47755 receiver chip.

the horizon, it is difficult to get reception on the ground in urban areas, especially in central and northern Europe.

To overcome this problem, SISNeT (Signal in Space through the Internet) was developed, which transmits EGNOS corrections over the internet to users, primarily via wireless phone networks. SISNeT can be implemented via software on a smart mobile phone with an internet connection and a built-in GPS, or built into specialised navigation devices.

In 2011, EGNOS was certified for "Safety of Life" applications such as aircraft navigation and landing under instrument flight conditions using a GPS approach to a runway.

From 2020 onward, experiments will start on EGNOS Version 3 with dual frequency downlinks on both the L1 (existing) and the L5 bands as well as the use of multiple constellations (other GNSS systems).

MSAS and QZSS – Japan

The Multi-functional Satellite Augmentation System has operated since September 2007. A typical navigation fix obtained is within 1.5-2.0m accuracy. It is primarily used for aviation purposes (see Fig.6).

Japan's other SBAS system is the Quasi-Zenith Satellite System, which is designed to work with the GPS system. As distinct from MSAS, it is primarily intended to be used in the heavily built-up urban areas in Japan's cities and mountainous regions where it is difficult to lock onto a

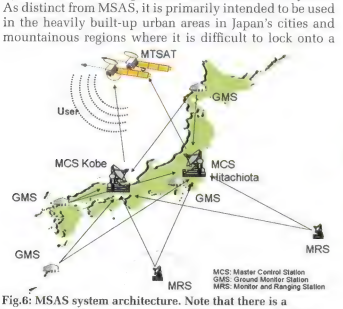


Fig.6: MSAS system architecture. Note that there is a monitoring and ranging station (MRS) in Australia. While correction data is not valid for Australia, with the addition of extra ground reference stations this system has been determined to be able to be expanded for use in Australia. Image credit: Irene Hidalgo.

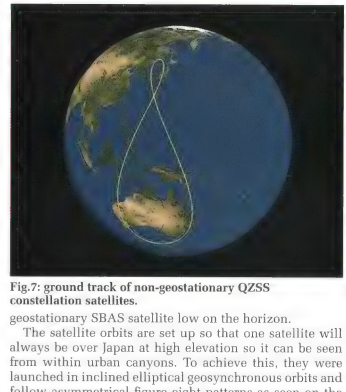


Fig.7: ground track of non-geostationary QZSS constellation satellites.

geostationary SBAS satellite low on the horizon.

The satellite orbits are set up so that one satellite will always be over Japan at high elevation so it can be seen from within urban canyons. To achieve this, they were launched in inclined elliptical geosynchronous orbits and follow asymmetrical figure eight patterns as seen on the ground (see Fig.7).

The first satellite was launched in 2010 and then an additional three satellites were launched in 2017 with the four satellite system expected to become fully operational this year (2018).

The QZSS system is compatible with existing GPS receivers with no modification. The system is designed to be able to achieve sub-metre accuracy (see Fig.8).

The positioning services offered by QZSS include the Satellite Positioning Service which will provide the same accuracy as GPS, the Sub-Meter Level Augmentation Service with an accuracy of 2-3m, the Centimeter Level Augmentation Service with an accuracy of about 10cm and Position Technology Verification Services for new positioning technologies as they are developed.

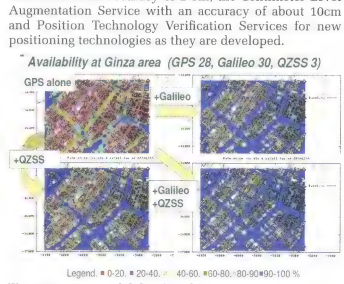


Fig.8: coverage availability (i.e, the proportion of time a navigational fix can be obtained) in Ginza using GPS alone, using GPS and Galileo together, GPS enhanced with QZSS; and GPS enhanced with combined Galileo signals plus QZSS. The more blue in the images the better. Image source: JAXA, Japan Aerospace Exploration Agency.

GAGAN – India

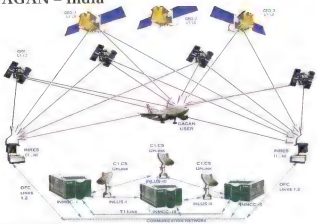


Fig.9: GAGAN system architecture.

India was the fourth country to establish an SBAS system after the US, EU and Japan, with its GPS Aided Geo Augmented Navigation system, starting July 2013. It is managed by the Airports Authority of India and is primarily designed for air navigation but has other uses.

It meets the requirements of international aviation bodies for "safety of life" operations and has a horizontal accuracy of 1.5m and 2.5m vertical (see Fig.10).

GAGAN uses three geostationary satellites transmitting on the L1 and L5 bands, 15 Indian Reference Stations (INRES), the Indian Master Control Centre (INMCC) comprising three sites to process the correction data from INRES and three Indian Land Uplink Stations (INLUS) to transmit data to the GAGAN satellites (see Fig.9).

An additional function of GAGAN is for ionospheric research. The ionosphere is relatively unstable over the Indian region and data will be used to design better algorithms for ionospheric corrections.

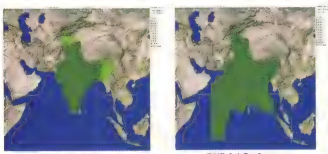


Fig.10: planned performance of GAGAN within specified coverage areas within the Indian Flight Information Region (FIR) for aviation. APV is Approach with Vertical guidance and RNP is Required Navigation Performance.

SDCM – Russia

The System for Differential Correction and Monitoring is designed to provide correction and integrity data for both GPS (USA) and Russia's GLONASS system. It has 19 ground stations in Russia and four abroad, with a processing centre in Moscow (see Figs. 11 & 12).

SDCM can provide a positioning accuracy of 1-1.5m horizontally and 2-3m vertically for normal users but can provide centimetre level accuracy within 200km of ground stations. Correction data can also be delivered over the Internet via SISNeT.

Work is also underway to develop Precise Point Positioning (PPP) for GLONASS. This technique is of interest because traditional techniques used with SBAS (real-time kinematics) lead to greater inaccuracy the further a user is from a base station, so a high density of base stations is required.

PPP does not require any base stations to work and an algorithm is used that accurately incorporates numerous effects known to affect GNSS signals such as tropospheric refraction, earth crust movements and ocean tides, antenna phase centre shifts, phase spin and relativistic effects. PPP can provide centimetre level accuracy without needing base stations (see section on NASA GipsyX and panel on PPP).

The use of L1, L5 and L6 signals

Currently, SBAS systems that use GPS satellites operate on the L1 band (centred at 1575.42MHz) but in the future, they will also use the L5 band, centred at 1176.45MHz (some already do). If an SBAS system observes both frequencies simultaneously, it is possible to directly measure the ionospheric delay of a GNSS signal to a much greater degree than just using the L1 alone.

Also, the L5 signal is more immune to ionospheric storms and the use of two frequencies gives some redundancy in case one of the transmission bands suffers from interference. Since 2009, all new GPS satellites have been equipped to transmit navigational data using L5 signals.

The Japanese QZSS system transmits an L6-band signal at 1278.75MHz with a data rate of 2000bps and if utilised, has the capacity to deliver real-time accuracy of 5cm horizontally and 10cm vertically, using PPP techniques.

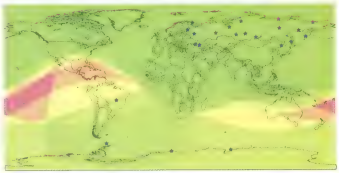


Fig.11: location of SDCM ground stations around the world.

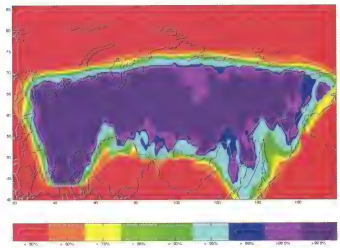


Fig.12: availability of SDCM in coverage area, mostly over the Russian Federation.

Precise Point Positioning (PPP)

PPP is an alternative method for providing correction data to GNSS receivers. Whereas DGNSS requires ground reference stations with precisely known locations to obtain corrections, no reference stations are needed for PPP.

In DGNSS, satellite orbit and clock errors are determined or estimated and transmitted to the receiver (called the "rover"), whereby the receiver applies the corrections to raw observations at the rover.

In PPP, position coordinates are calculated with respect to the navigation satellite's reference frame in space, not a specific ground reference station. Therefore, PPP should work globally, unlike SBAS which has a specific service area depending on how many ground reference stations have been installed.

PPP requires precise mathematical models, such as NASA's GipsyX, which take into account a large number of very subtle sources of error (see main text). After a control centre calculates the corrections, they are transmitted to the rover. The extremely accurate calculations made with PPP enables a higher level of accuracy than DGNSS.

Another advantage of PPP is the possibility of reduced cost because a network of ground reference stations does not need to be maintained and corrections can possibly be transmitted to the rover with less bandwidth required than for DGNSS. A disadvantage of PPP at the moment is relatively long times to obtain a position fix or "convergence".

Starfire – John Deere (commercial)

The StarFire navigation system is commercially operated by John Deere and used in precision agriculture for vehicle guidance (See Figs. 13 & 14). Also see the article about Agbots in the June 2018 issue of SILICON CHIP for more information on its usage: www.siliconchip.com.au/Article/11097

StarFire broadcasts correction signals from satellites on L-band frequencies to give high levels of position accuracy. John Deere operates a number of ground reference stations around the world, including Australia, to generate the correction signals. Unlike other SBAS systems, the correction accuracy is said to be independent of the distance from a ground station.

StarFire receivers use L1 and L2 frequencies from GPS satellites. The encrypted military P(Y) signal on L1 is used in conjunction with the P(Y) L2 signal to accurately calculate ionospheric delays. It cannot decrypt the P(Y) signal but just uses phase information of the two signals to make the calculations.

The internal position fix calculated within the GPS receiver may be further enhanced with external correction signals, depending on the level of accuracy chosen and therefore subscription fee paid.

According to a John Deere (Australia) online brochure for the StarFire 6000 receiver, the following levels of service are available:

- SF1: ±150mm accuracy, no repeatability; position drifts over time. No subscription is required. Initial position determination takes 10 minutes.
- SF2: ±50mm accuracy, no repeatability; not available for StarFire 6000 receiver, subscription required to receive correction signals. Initial position determination takes 90 minutes.
- SF3: ±30mm accuracy with in-season repeatability, subscription required to receive correction signals. Initial position determination takes less than 30 minutes.
- Radio RTK: ±25mm accuracy with long-term repeatability, subscription required to receive correction signals unless using own base station (see Fig.13). Initial position determination takes less than one minute.
- Mobile RTK: ±25mm accuracy with long-term repeatability when mobile phone signal available, subscription required to receive correction signals. Initial position determination takes less than one minute.

GipsyX (PPP) – NASA

GipsyX is a set of real-time GNSS data processing techniques and software developed by NASA to obtain global corrections for GNSS satellites. It improves the accuracy of GNSS systems such as GPS and GLONASS (Galileo and BeiDou support is being developed) by modelling complex and subtle effects that lower the accuracy of GNSS devices.

GipsyX enables Precise Point Positioning (PPP; see separate explanatory panel).

Effects taken into account include:

- Short-term and long-term changes in the Earth's orientation, including polar motion and variations in Earth's axial rotation angle (UT1).
- Solid Earth body tide deformations.
- Ocean tide loading deformations.
- Transmitter and receiver antenna calibrations.
- Satellite attitude variations.
- Phase wind-up, which relates to the fact that satellites

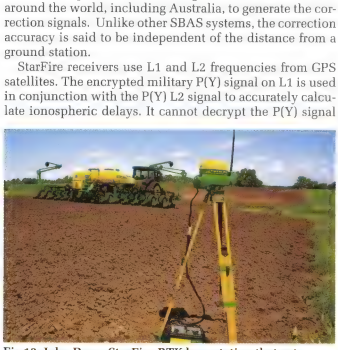


Fig.13: John Deere StarFire RTK base station that acts similarly to other SBAS base stations. It provides a repeatable 2.5cm accuracy.

Fig.14: John Deere guidance display inside tractor or similar vehicle.

must rotate to keep their solar panels pointed toward the Sun. This rotation causes the phase of the radio signal to change with respect to the receiving antenna and this is misinterpreted as a variation in range, with an error of around 10cm.

- Quaternion compensation for vehicle attitude such as spacecraft and aircraft. A quaternion represents the relative rotation of two coordinate systems such as between a spacecraft and a fixed frame of reference such as earth or another spacecraft; only rotational orientation is considered.
- General relativity (as described by Albert Einstein).
- Crustal plate motion (eg, Australia moving north-east at around 7cm per year).
- Second order ionospheric corrections. First order ionosphere delay corrections based on the L1 and L5 transmissions can give centimetre level accuracy but second order effects need to be taken into account for millimetre accuracy. These stem from the change in polarisation of radio waves as they travel through the Earth's magnetic field (Faraday rotation), leading to an error of 1-10mm.
- The effects of a dry or wet troposphere (the lowest 6-10km of the atmosphere) on signal delay. This involves one of several mapping functions; either GPT (Global Pressure and Temperature model), GMF (Global Mapping Function), VMF (Vienna Mapping Function) or NMF (Niell Mapping Function).

Additionally, GipsyX takes into account for orbiting space vehicle complex force models that include:

- High-order Earth static gravity fields.
- Atmospheric drag.
- Solid earth, ocean, and pole tide gravity fields.
- Solar and terrestrial radiation pressure.
- General relativity.
- Third body effects from the Sun, Moon and other planets.
- Custom and general models of spacecraft shape.

C-Nav – Oceaneering (commercial)

C-Nav Positioning Solutions is commercially operated by Oceaneering. It uses the technique of Precise Point Positioning (see panel) and is generally known as GcGPS or Globally corrected GPS.

It generates correction data by a proprietary implementation of NASA's GipsyX software and it broadcasts orbit and clock corrections for all GNSS satellites simultaneously from its own satellites.

It is available all over the world from 72°N to 72°S latitude. Typical accuracy is better than 5cm horizontally and 15cm vertically. It has over 40,000 users worldwide, on a subscription basis. Proprietary receivers are required to use this system.

C-Nav works as follows. Worldwide Global GPS Network (GGN) ground reference stations collect dual frequency L1 and L2 data (other frequencies such as L5 may be used). This data enables ionospheric and other measurement to be made. The raw data is transmitted to two "hot" Network Processing Hubs plus a backup hub via the internet.

Independent Refraction Corrected Orbit and Atomic Clock Offset corrections for all GPS satellites are then computed by the Network Processing Hubs. Corrections are then sent via an uplink to geostationary satellites whereupon they are retransmitted to users (see Fig.18).

How changes in the Earth's shape affect accuracy

With navigation systems becoming so accurate, it is important to consider what frame navigational data is referenced to since the Earth is constantly changing shape due to continental drift, uplift, subsidence and other factors. This affects both the notional altitude and position at any point near the Earth's surface.

The GPS system was originally referenced to the US Department of Defense World Geodetic System of 1984 or WGS 84 (now called WGS 84 [Original]). It was actually defined in 1987 with a world survey done using Doppler satellite surveying techniques.

WGS 84 (Original) was upgraded in accuracy using GPS measurements in 1994, to WGS 84 (G730). It was again upgraded to WGS 84 (G873) in 1996 to be more closely aligned with the International Earth Rotation Service (IERS) Terrestrial Reference Frame (ITRF) 94.

It was then called WGS 84 (G873) and used from 1997. In 2002, WGS 84 (G1150) was implemented and followed by WGS 84 (G1674) from 2012.

Unfortunately, the Earth continues to change shape and the difference in position using WGS 84 (Original) at the present can be 1-2 metres, perhaps more. The International Earth Rotation Service (IERS) computes the positions for specific sites on the Earth on a regular basis and the data is fed into the International Terrestrial Reference Frame (ITRF) for the current epoch (time period).

The ITRF is an internationally accepted standard and the most accurate geocentric reference system, and so it is the reference frame used for SBAS corrections. WGS 84 (G1674) agrees with ITRF to within about 10cm.

In Australia, the current reference frame is the Geocentric Datum of Australia 1994 (GDA94). However, since this was established in 1994, the Australian tectonic plate has shifted by 1.6m meaning that Australian coordinates are no longer aligned with GNSS coordinates such as GPS (based on WGS 84), making high accuracy navigation impossible.

Australia has therefore implemented the Geocentric Datum of Australia 2020 (GDA2020), based on the projected position of the Australian continent on the Earth's surface in 2020. If this datum is used now, the offset from GNSS coordinates such as GPS will be 20cm but they will converge in 2020. GDA2020 is closely aligned with ITRF2014.

Starfix – Fugro (commercial)

The Starfix system by Fugro is a commercial system primarily aimed at navigation for offshore construction vessels, survey operations, pipe laying and cable laying activities, seismic surveys, dive support and installation and monitoring of floating storage of offshore oil and gas at the point of production.

Their correction data is delivered via satellite or the Internet in a proprietary compressed format. It works with GPS, GLONASS, BeiDou and Galileo. Centimetre, decimetre and sub-metre accuracies are available. For regions at high altitude beyond about 75°N or 75°S, beyond the reach of their geostationary satellites, correction data is delivered by Iridium satellites which are in polar orbit and have global coverage.

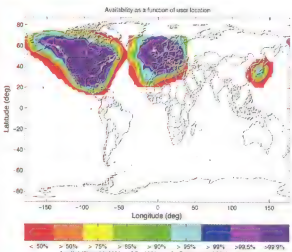
A variety of services are available:

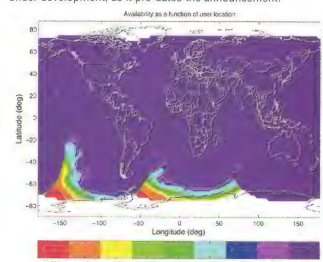
Possible future for SBAS

Fig.15 (below left) shows SBAS coverage in 2013 while Fig.16 (right) shows the predicted coverage (at the time) for 2020-2025, showing near-global access.

This includes WAAS, EGNOS and MSAS with an enhanced system including SDCM and GAGAN as well as dual frequency GNSS (L1 and L5 bands) and an expanded network of stations in the Southern Hemisphere.

The figures come from the European Space Agency and do not include any possible contribution from the Australian SBAS system under development, as it pre-dates the announcement.





- Starfix.L1 is a single-frequency system using L1 and can provide a position fix within one metre.
- Starfix.XP2 uses GPS and GLONASS and obtains orbit and clock corrections from a third party with further corrections by Fugro software. It uses Precise Point Positioning (PPP; see panel). Accuracies of better than 10cm horizontally and 20cm vertically can be obtained.
- Starfix.G4 uses GPS, GLONASS, Galileo and BeiDou with clock and orbit corrections provided from Fugro's own network of ground reference stations, with additional corrections provided by proprietary software. Accuracies better than 10cm horizontally and vertically can be obtained.
- Starfix.G2 is a subset of Starfix.G4 but uses only GPS and GLONASS.
- Starfix G2+ uses GPS and GLONASS with clock and orbit corrections enhanced with carrier phase corrections from the Starfix.G4 network, plus in-house augmentation algorithms. Better than 3cm horizontal and 6cm vertical accuracy can be achieved.

OmniSTAR – Trimble (commercial)

The OmniSTAR system, owned by Trimble, is another commercial augmented GNSS service. OmniSTAR correction signals are proprietary in nature and service is avail-

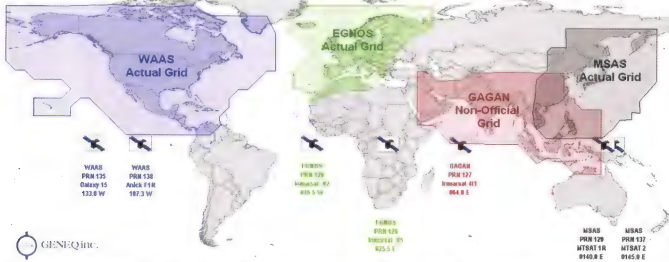


Fig.17: existing free-to-air SBAS service areas showing positions of geostationary satellites that transmit correction data. Australia, Antarctica, Africa and South America are the four main land masses not currently covered by SBAS. Initiatives are under way to provide SBAS in Africa as an extension of EGNOS, South America with SACCSA (Solución de Aumentación para Caribe, Centro y Sudamérica / Augmentation Solution for the Caribbean, Central and South America) and Malaysia and South Korea with KASS (Korean Augmentation Satellite System to be in place by 2021).

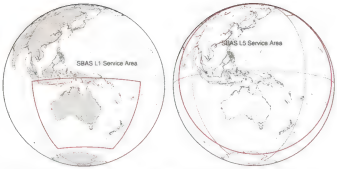


Fig.18: Coverage for single frequency (L1) and dual frequency (L5) SBAS test. Image source: Geoscience Australia.

able in most areas of the world, including Australia. Their services include:

- OmniSTAR HP, their premium service uses an L1/L2 dual frequency receiver. It has an accuracy of 10cm.
- OmniSTAR G2 uses GLONASS satellites and correction data and is suitable for use in areas with limited satellite visibility such as mountainous regions, heavily vegetated and built-up areas. Accuracy better than 10cm is possible.
- OmniSTAR XP is a dual-frequency system with orbit and clock correction, with a long-term repeatability of 10cm and is suitable for precision agriculture.
- OmniSTAR VBS is the basic single frequency service using L1 and receives correction data from regional ground reference stations. An accuracy of better than 1m can be achieved.

Other augmentation systems

Wide Area GPS Enhancement (WAGE) is an obsolescent system of the US Military with an uncertain service status. It is used to improve the horizontal accuracy of the encrypted GPS signal used by the military, on specialised receivers.

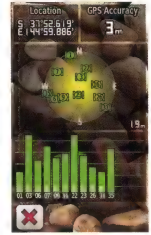


Fig.19: a typical hand held consumer GPS display showing the positions and signal strength of the satellite signals being received. Note the "D" in the signal strength bars indicating a correction signal (or differential signal) is being received for that particular satellite. The correction signal is transmitted by a different satellite than the GPS satellites. This correction signal is being received because of the SBAS test bed now operating in Australia.

The military GPS signal is encrypted to prevent an enemy spoofing the signal to cause an inaccurate position fix.

Modern standard GPS receivers outperform WAGE. WAGE has been superseded by Talon NAMATH, about which there is little published information and any existing WAGE users are being encouraged to use it.

Conclusion

As shown in the panel on future predictions of SBAS availability, in the near future, enhanced or augmented GPS will be available over all occupied areas of the Earth's surface and most of the oceans.

This will mean that pretty much everyone will be able to determine his or her own position to within about 1m on the Earth's surface, making vehicle and personal navigation substantially more reliable.

It will also enable many new technologies which are not practical with the present ~5m typical inaccuracy, as described in the introduction. SC

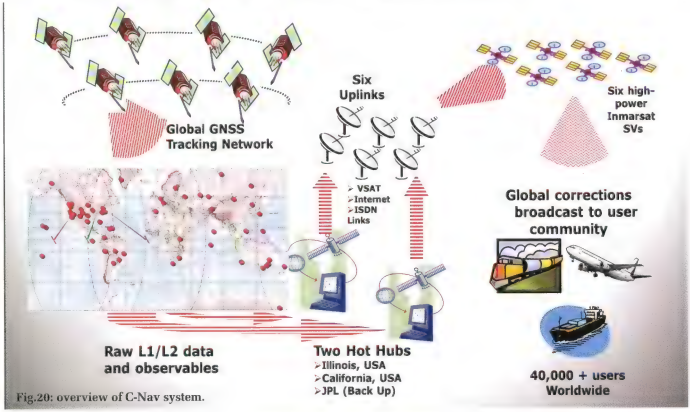
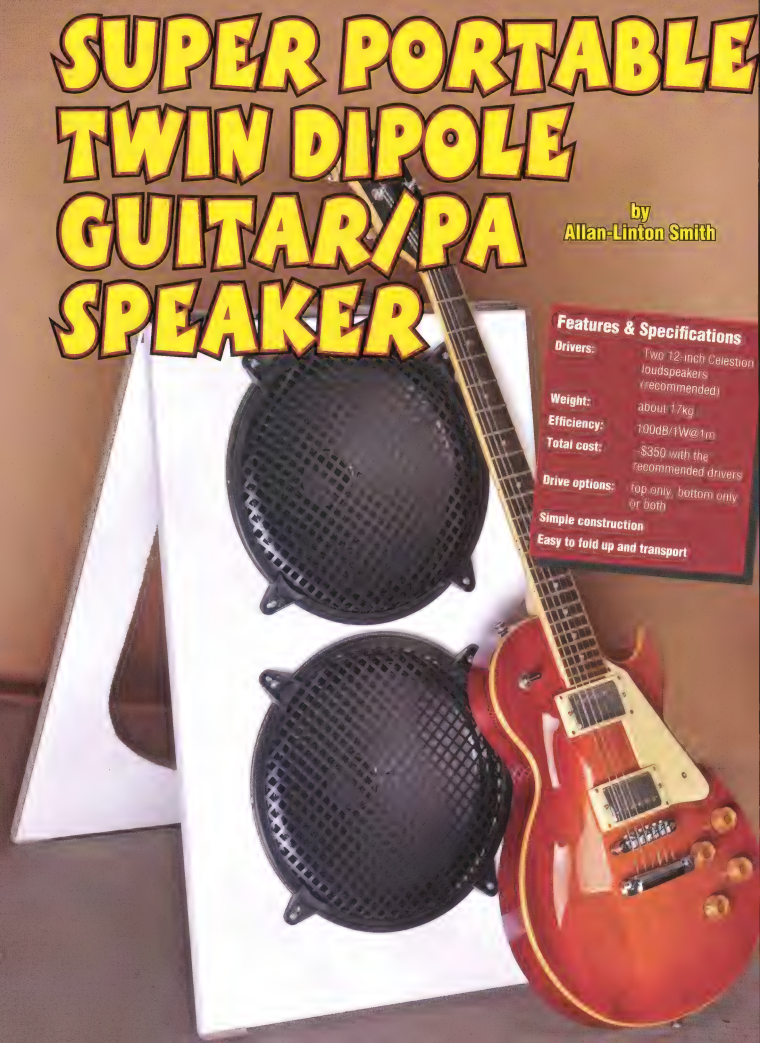


Fig.20: overview of C-Nav system.

SUPER PORTABLE TWIN DIPOLE GUITAR/PA SPEAKER

by Allan-Linton Smith



Features & Specifications

Drivers:	Two 12-inch Celestion loudspeakers (recommended)
Weight:	about 17kg
Efficiency:	100dB/1W@1m
Total cost:	$350 with the recommended drivers
Drive options:	top only, bottom only or both

Simple construction

Easy to fold up and transport

This guitar/PA speaker is dead easy to build and it's really portable. It's also LOUD and it sounds great. When on stage, you can project plenty of sound to the crowd while still being able to hear your own playing (no foldbacks needed). If you build it using our recommended drivers (as used by Jimi Hendrix and Slash), it has a mellow, old-fashioned tone. But you can also use different drivers for a more modern, harder sound.

Because of the way this speaker is designed, it can be folded flat for easy transport and can be built by anyone with only rudimentary carpentry skills and tools.

You can easily build it in a day, with a perfect finish and a professional appearance. You can even choose from a range of colours to suit your band!

Guitarist Marcus Child, (from the band "Country Members"), putting the dipole speaker through its paces.

Choice of drivers

One of the great things about this design, besides the advantages laid out above, is that you can choose from a range of drivers which have their own unique sound.

And because it's a twin-driver rig, you can use two different ones (as we have done), giving you the option of three different tones: upper driver only, lower driver only or both together.

The drivers we are recommending come from a series with a long history. They have been used by some people you may have heard of including Angus Young, Jimi Hendrix, Slash, Eric May, Brian Gibbons and Eddie Van Halen.

While you can use just about any two 12-inch (30cm) drivers, we are recommending Celestion units in this project for several reasons.

One, they are good quality. Two, they are designed to provide a tone to suit an electric guitar. And three, there are 22 different drivers in the series to choose from with their own unique sound profiles, power levels and efficiencies.

This includes four from Celestion's Heritage series, three from the Alnico series, one from the Signature series (the Eddie Van Halen), 14 from the Classic Series and two from the Originals series.

You can see a list of suitable drivers at: https://celestion.com/product/26/heritage_series_g1265/

For many of the drivers, audio samples of guitar playing are provided, allowing you to get an idea of what it sounds like before purchase.

Note that this list includes some drivers which are not suitable, ie, those which are not 12 inches (305mm) in diameter or those which are not available with a 15-ohm or 16-ohm nominal impedance.

The maximum power level of the suitable Celestion drivers ranges from 15W up to 100W.

Our unit uses the G12M Greenback and Vintage 30 drivers, which are rated at 96dB @ 1W, 20W maximum and 100dB @ 1W, 60W maximum respectively.

Since these are from the Heritage and Classic series, they give a laid-back sound with plenty of mid bass and high-end. If that isn't your bag, see below for some other options.

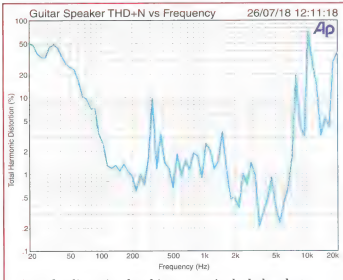


Fig.1: the distortion level is not particularly low but sometimes, that's what a guitar player actually wants!

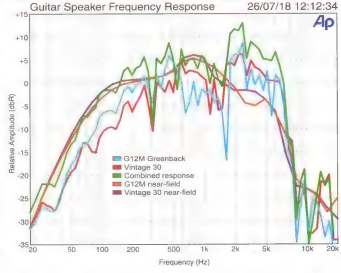


Fig.2: the usable frequency response is from 80Hz to about 8kHz – more than enough for guitar and even PA use.

The G12M was a favourite of Jimi Hendrix; he used a whole raft of them to handle his powerful riffs and was also used extensively by Eddie Van Halen.

On the other hand, the Vintage 30 has been used by Slash, Steve Stevens and Peter Frampton. They're both available through Australian distributors; see the parts list for details.

These drivers are designed to be rugged and use paper cones with a small amount of doping. They are also very sensitive and are generally rated at 96-100dB/watt at one metre because the lead guitar has to be LOUD!

Not your grandpa's guitar speaker

Traditionally, guitar speakers consist of a small wedge-shaped box with one to four drivers arranged along the front. These generally have no acoustic filling, bracing or damping and often have a resonant or "boxy" sound which accentuates notes played at the resonant frequency of the box. This gets boring pretty quickly.

Our aim for this project was to provide the guitarist with a sound which specifically suits their instrument. That's quite a personal thing but since the enclosure is customisable, that's no problem!

We settled on a "dipole" arrangement of two 12-inch drivers which can be used individually or together, depending on whether you're practising or performing. If you have multiple electric guitars, you may find that some work better with one driver while others sound best with the second driver. Vive la différence!

The speaker's "angle of attack" can also be easily adjusted to suit different venues. The dipole completely removes cabinet colouration so that the resulting sound is quite neutral across the entire audio spectrum. Basically, you're just hearing the characteristics of the driver, which is determined by the manufacturers.

And since the drivers we're using are specifically intended for lead or rhythm guitars, that's the ideal situation.

The sound from the dipole setup is not terribly directional; that is to say, it doesn't matter terribly where you point it because the sound is much the same at the back, front or sides.

So not only is it its own foldback speaker, the crowd will enjoy your gig regardless of whether they are right in front of the speaker or off to the side.

Testing it out

We had our resident guitar player, Bao Smith, test the speaker and he confirms that it has the most important property that any guitar speaker needs: it can definitely make a lot of noise and sounds good doing so!

Allan also had his guitar-crazy mate Marcus test it out in an extended jam session, using a Gibson guitar and 30W valve amplifier.

Afterwards, he commented: "It's great for a lead guitar and has plenty of volume which will rise above the other instruments in my band." (We had to wear hearing protection while he was playing!)

I made an efficiency measurement with both speakers connected in parallel and got a result of 105dB/watt at one metre – that's pretty amazing!

We have made some performance measurements but remember that this speaker is not intended for hifi use, so we aren't looking for ultra-low distortion. In fact, many guitar players like having plenty of distortion!

A plot of distortion against frequency for the two drivers in parallel is shown in Fig.1 and you will notice that distortion is very high below 80Hz and above 7.5kHz. That's because these frequencies are outside the response of the drivers and so the sound level is dropping off quite significantly. Anything below about 60Hz has too great a drop-off to be audible.

There are some spikes at intermediate frequencies (eg, around 320Hz) but these could be measurement artefacts as they do not seem to be audible.

Fig.2 shows the frequency response of the two individual drivers plus the combined drivers. These are very "noisy" measurements due to the fact that the microphone has been placed some distance away from the speaker in order to provide a realistic result. But room resonances and interference then affect the readings.

The "near-field" responses, taken with the microphone right in front of the two drivers, do not suffer from this. In any case, you can see that all of the responses start to fall off below about 100Hz and above 6-7kHz.

That's a pretty wide range for a single driver.

The lowest string on a six-string guitar is normally tuned to 82Hz (E) while the highest fret on the highest string is normally tuned to 1047Hz (see fret table).

The speaker response covers this entire range of frequencies with plenty of room on top for harmonics. Of course some of the more popular alternative tunings (drop-D) have lower frequencies (73Hz).

Frequency	G12M	Vintage 30	Combined
20	14.6	19.1	8.6
25.2	15.6	22.2	9.5
31.7	17.2	28	11
39.9	20.2	40.9	13.8
50.2	27	80.6	21.2
63.2	48.6	169	51.2
79.6	127	54.6	32.5
100.2	33.8	29.9	14.5
126.2	20.6	21.3	10.2
158.9	16.5	17.5	8.6
200	15.2	15.9	8
251.8	14.9	15.1	7.9
317	15.3	15.4	8.1
399.1	16	16	8.4
502.4	16.6	17.1	8.9
632.5	17.5	19.2	9.6
796.2	19.7	18.9	9.6
1002.3	19.7	15.3	9.8
1261.9	21.1	20.1	10.5
1588.6	23	22.6	11.6
2000	26.2	24.4	12.8
2517.8	29.9	26.6	14.3
3169.7	31.6	29.6	15.4
3990.5	35.2	33.9	17.3
5023.7	39.8	35.3	18.9
6324.5	42.4	37.6	20
7962.1	48.6	42.9	22.8
10023	55.8	48.8	26.1
12619	64	55.8	29.7
15886	73	64.2	34.1
20000	84.2	72.2	38.6

Fig.3: the combined impedance from both drivers barely dips below 8 ohms, so should not be a problem for the vast majority of amplifiers (even "hifi" amps!). We even succeeded driving it from the headphone output of a guitar amp.

Speaker impedance

We're using the 16Ω version for both speakers, so when driven in parallel, they present a modest 8Ω

The two 12-inch drivers we're recommending, both from Celestion. At left is the G12 M Greenback; at right is the Vintage 30. You *can* substitute other drivers but we can't guarantee that they will perform as well as these do.

load to the amplifier. The impedance of each combination of drivers is shown in Fig.3 and this shows that when driving both in parallel, it barely dips below 8Ω.

So any amplifier should be able to easily drive them both. The resonance peaks (clipped off) are 127Ω at 80Hz for the G12M and 159Ω at 63Hz for the Vintage 30.

You could use 8Ω drivers instead, indeed, there are 8Ω versions of both drivers specified; the Altronics driver mentioned below is 8Ω only. In this case, make sure that your amplifier will handle a 4Ω load; most will and they will typically deliver more power into a 4Ω load than an 8Ω load. So if you're building the speaker with high-power drivers, that will be your best option.

Note though that if you do this and then you add more speakers in parallel (eg, monitors), the combined impedance may fall below 4Ω and overload your amplifier. Many guitar amps are valve-based and since they require output transformers, they usually have several output impedance taps, which may influence your selection.

Choosing an amplifier

The reason guitarists tend to prefer valve amplifiers is for the way they sound when they're overdriven, as a valve amplifier will typically sound better than a solid-state one when driven to its limit. This speaker works really well with valve amplifiers because of the fact that it has a relatively high impedance and because of its high efficiency, which suits the relatively low power output of a typical valve amplifier.

But you certainly can use it with a solid state amplifier and it doesn't necessarily have to be a guitar amp. As long as you have appropriate signal conditioning (ie, some form of guitar preamp), you could use a hifi or PA amplifier too. You don't even need to use it with a guitar!

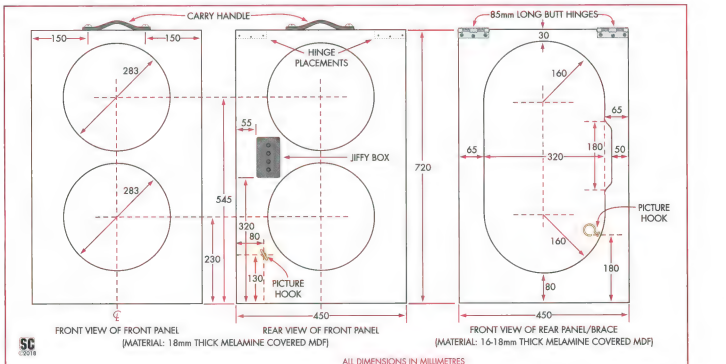
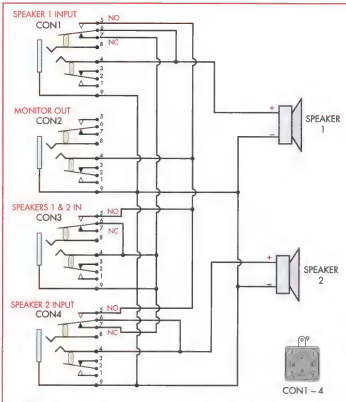


Fig.4: cutting diagram for both the front and rear of the dipole speaker panels, which are joined at the top with butt hinges to form an A-frame. We used Kaboodle door panels from Bunnings but chipboard, MDF etc would be fine.



GUITAR SPEAKER CIRCUIT

Fig.5: the circuit is very simple indeed, basically it is just the four 6.35mm sockets and some wiring between them and to the speakers.

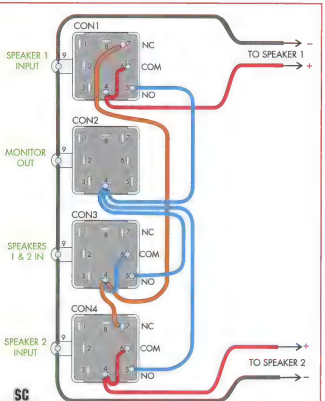


Fig.6: and here's a pictorial view of that wiring. The labelling of the four input sockets coincides with the panel artwork shown in Fig. 7.

You could use it with a different type of electric instrument like a synthesiser, bass, harpejji or you could connect a microphone and a suitable preamp/amplifier and use it as a portable PA system.

Sourcing the timber frame

The two halves of the "sandwich board" are made from Bunnings Kaboodle kitchen cabinet doors which measure 720x450x18mm. We purchased these in gloss white but there are many other colours to choose from.

Why not try a piano black finish, or be daring and go for "seduction red" in full gloss, or a more conservative "Myrtle gloss"? Many Bunnings outlets have samples of their finishes on display so you can look at and touch them before deciding. Note that gloss white is usually in stock at most Bunnings stores but other colours may need to be ordered and will take about two weeks to arrive.

We used Kaboodle cabinets to build the Majestic (June & September 2014; siliconchip.com.au/Series/275) and Senator (September & October 2015; siliconchip.com.au/Series/291) speakers. They have very good acoustic properties.

You could also use plywood, MDF or any other material instead as long as it is at least 18mm thick. The rear support is not critical and 16mm thick material (eg, melamine-coated fibreboard) is suitable. The two halves are attached at the top with two 85mm stainless steel hinges.

Junction box operation

The circuit for the junction box is quite simple, as shown in Fig.5. It uses just four DPDT switched stereo jack sockets and some wiring to perform all the necessary functions. The sleeves of all four sockets are joined together to form a common ground connection, which is wired directly to the negative end of both drivers. All the signal routing is done to the positive side of the drivers.

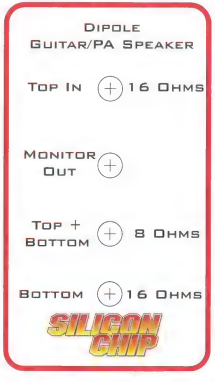


Fig.7: same-size front panel artwork for the Jiffy box mounted alongside the speaker drivers. You can also photocopy this (or download it from siliconchip.com.au to use as a drilling template for the four input sockets.

Each socket consists of the three usual contacts for a stereo socket – tip, ring and sleeve – plus two insulated double-throw switches which are actuated when a plug is pushed past the tip and ring contacts respectively. These switches are used to route the connections to provide the required functions.

CON2 is an output socket to go to a monitor amp (eg, driving headphones worn by the player) and the switch at pins 5, 6 and 7 of the other three sockets are connected such that when you insert a plug in any of those other sockets, its tip connection (at pin 4) is routed to the tip of the monitor socket, via the normally open contacts of the switches (pin 5).

This means it receives the input signal regardless of which driver(s) are being driven.

By the way, you should never plug your headphones directly into CON2 if you value either your headphones or your hearing!

The normally-closed half of the three double-throw switches is used to apply the signal to the correct loudspeaker, based on which socket you have inserted the plug into.

If you plug into CON1, the tip connection is wired directly to the positive terminal of SPEAKER1 so signal flows to that driver. The NC terminal of that socket's switch at pin 7 is no longer connected to pin 6 so the signal does not flow to the other driver.

Similarly, if you plug into CON4, the tip connection feeds the signal to SPEAKER2 but the switch is disconnected from anything but the monitor socket and so the signal does not go to SPEAKER1.

But if you plug into CON3, the signal from the tip is instead fed to the NC terminals of the switches in both CON1 and CON4 and since nothing is plugged into those sockets, the signal then flows to the positive end of both SPEAKER1 and SPEAKER2 via pin 6 on those sockets.

Construction

The assembly process is straightforward and assuming you have the right tools on hand, you should be able to go from an assortment of parts to a finished speaker in a few hours.

You need to make two circular cut-outs in the front panel and one large rounded-rectangle shape cut-out in the rear panel. The details are shown in Fig.4. Start by marking the 283mm driver cut-outs in the front panel using a compass, then carefully cut out the circles using a jigsaw.

Note that if you are using Kaboodle cabinets or similar coated timber then you should cut them from the reverse side using a good quality, fine tooth jigsaw blade (preferably a new one!).

Use a similar process to cut the large hole on the rear panel. You can mark the two circles in the same manner, then join them using a long straightedge before making the cutout.

Lay the two panels end-to-end and mark out the drilling locations for the hinge attachment screws. Drill small pilot holes (again using masking tape to protect the front finish), then attach the hinges to both panels using 15mm countersunk wood screws and check that the two boards fold correctly. They should fold flat against each other.

The next step is to attach the drivers. This is easiest to do if you fold the assembly together and support it horizontally between two stable benches or other supports. Drop the drivers into the holes and rotate them so that the labels on the back will be right-side-up, then mark out the mounting holes.

Remove the drivers and drill these with a pilot drill bit, then reinstate the drivers and attach them with 10mm countersunk wood screws through the front of each surround and into the front panel timber.

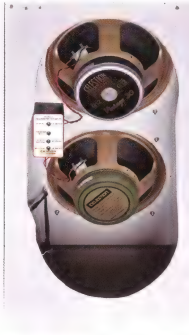
Now place the grilles on top of the driver surrounds, arrange the supplied mounting brackets around the edge (equally spaced), as shown in our photos, and mark the required hole positions for these brackets, then remove the brackets and drill pilot holes in those locations. Fix the brackets to the front panel using 20mm wood screws, ensuring that the grilles are held firmly in place.

You can now attach the handle to the top edge of the front panel, again by drilling pilot holes and then attach it with 40mm wood screws. Now is also a good time to stick the adhesive felt strips on the bottom of both panels, one at each end and one in the middle.

Next, drill a couple of pilot holes at corresponding points on the inside of the front and rear panels, so that you can

Parts list – A-frame Guitar/PA Loudspeaker

1 16-ohm Celestion Classic Series G12M Greenback 12-inch driver [Electric Factory (T1221) or Scarlett Music] ***and***
1 16-ohm Celestion Classic Series Vintage 30 12-inch driver [Electric Factory (T3904)]
or
2 8-ohm 12-inch 100W polypropylene woofers [Altronics C3070] (see text)
2 12-inch metal speaker protection grilles with mounting brackets [Altronics C3712]
2 Kaboodle 720x450x18mm kitchen cabinet doors [Bunnings] or plywood/MDF sheets (see text)
2 85mm stainless steel butt hinges [eg, Bunnings 4160027]
1 slim carry handle [Altronics C3660, Jaycar HS8022 or Bunnings 4230073]
8 No.3 x 10mm countersunk head wood screws (for mounting drivers)
4 No.3 x 20mm pan head wood screws (for grilles)
12 No.4 x 15mm countersunk head wood screws (for hinges)
2 No.3 x 40mm pan head or countersunk head wood screws (to suit handle)
2 No.4 x 10mm pan head wood screws (for mounting Jiffy box)
2 19mm cup hooks [eg, Bunnings 3930140]
1 350mm long cloth or rubber strap with loops at each end
or
1 400mm length of small diameter rope/blind cord
4 DPDT mono or stereo 6.35mm jack sockets, chassis-mounting [Jaycar PS0182, Altronics P0072]
6 heavy-duty adhesive 20 x 50mm felt strips (or larger strips cut to size)
1 UB3 bulkhead Jiffy box (130 x 67 x 44mm [not including flanges])
1 adhesive panel label for Jiffy box lid
1 1m length of speaker cable (or two 1m lengths of red & black heavy duty hookup wire)
various lengths of heavy-duty hookup wire (see Fig.6 for suggested colours)



Looking through the rear panel, showing the two speaker drivers and input box secured to the front panel. (Its position is not important – just make sure the rear panel cutout is large enough to accommodate it when closed). You can also just see the cord which stops the front and back panels opening too far.
(Yeah, we know we could have made the rear panel cutout a bit straighter . . .)

And when you've finished your gig, simply unplug the amplifier, fold the two halves together and carry the speaker away. Mind you, at about 17kg (most of which is the two 12-inch drivers), we hope you don't have to walk too far! This photo also shows why such a large cutout is required on the rear panel (otherwise you would be able to fold the front and back flat).

screw in the cup hooks and then tie the cloth strap or cord between them, to limit how far the assembly will open. This prevents it from falling over when in use. Adjust the length of the strap until you are happy with the angle that the panels sit at when opened up.

Junction box assembly

The first step is to drill four holes down the centre of the Jiffy box lid and then enlarge them (using a stepped drill bit or tapered reamer) until the sockets are a good fit, without being too loose.

The panel label shown in Fig.7 can be used as a template to space these holes. It can be photocopied or, if you prefer, downloaded from siliconchip.com.au/Shop/11/4688.

Stick on the panel label and cut out the socket holes with a sharp hobby knife. You can print it and laminate it, then attach it using contact adhesive or silicone sealant. Or you could print it mirrored on transparent film and glue it on with the ink towards the lid, using a thin smear of clear silicone sealant.

You can also get adhesive-backed paper for inkjet and laser printers which you can simply cut out and stick on to the lid. For more information, see our website at siliconchip.com.au/Help/FrontPanels for details.

With the label in place, attach the sockets using the supplied nuts and then solder various short lengths of heavy-duty hookup wire between the sockets, as shown in Fig.6. This makes the connections as shown in the circuit diagram, Fig.5. Note that several amps can flow through this wiring if you're driving the speaker hard, hence our recommendation to use heavy-duty wire.

You can use the same wire, twisted together, to connect to the drivers. That's how the prototype was built. Or you could use figure-8 speaker wire, which would be a little neater. Solder the four speaker wires to the socket terminals as shown in Fig.6, then drill a small hole in the side of the Jiffy box and feed the speaker wires out through this hole, then solder them to the tabs on the drivers.

Make sure that the wires for SPEAKER1 go to the top driver and the wires for SPEAKER2 go to the bottom driver and don't get the positive and negative wires mixed up or you will get sound cancellation when using both speakers at the same time.

Next, drill a couple of holes in the Jiffy box base and two corresponding pilot holes in the back side of the front panel. You can then feed a couple of short wood screws through the inside of the Jiffy box and into the holes on the panel, then screw the lid onto the box and the whole assembly should be firmly attached to the speaker. Refer to the photo above to figure out the best location for mounting this box.

That's it – your speaker is finished. Now all you have to do is connect a lead from your guitar amplifier's external output socket to one of the three input sockets on the Jiffy box and you're ready to jam! SC

Guitar

FRET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	E	F	F#	G	G#	A	A#	B	C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C
	330	349	370	392	415	440	466	494	523	554	587	622	659	698	740	784	831	880	932	988	047
	B	C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C	C#	D	D#	E	F	F#	G
	247	262	277	294	311	330	349	370	392	415	440	466	494	523	554	587	622	659	698	740	784
	G	G#	A	A#	B	C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C	C#	D	D#
	196	208	220	233	247	262	277	294	311	330	349	370	392	415	440	466	494	523	554	587	622
	D	D#	E	F	F#	G	G#	A	A#	B	C	C#	D	D#	E	F	F#	G	G#	A	A#
	147	156	165	175	185	198	208	220	233	247	262	277	294	311	330	349	370	392	415	440	466
	A	A#	B	C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C	C#	D	D#	E	F
	110	117	123	131	139	147	156	165	175	185	196	208	220	233	247	262	277	294	311	330	349
	E	F	F#	G	G#	A	A#	B	C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C
	82	87	92	98	104	110	117	123	131	139	147	156	165	175	185	196	208	220	233	247	262

Note and frequency in Hertz (approx.) for standard tuning.

Bass

G	G#	A	A#	B	C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C	C#	D	D#
98	104	110	117	123	131	139	147	156	165	175	185	196	208	220	233	247	262	277	294	311
D	D#	E	F	F#	G	G#	A	A#	B	C	C#	D	D#	E	F	F#	G	G#	A	A#
73	78	82	87	92	98	104	110	117	123	131	139	147	156	165	175	185	196	208	220	233
A	A#	B	C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C	C#	D	D#	E	F
55	58	62	65	69	73	78	82	87	92	98	104	110	117	123	131	139	147	156	165	175
E	F	F#	G	G#	A	A#	B	C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C
41	44	46	49	52	55	58	62	65	69	73	78	82	87	92	98	104	110	117	123	131

Fig. 8: we show this more for interest sake than anything else – it's the frequencies of each note when either a rhythm or bass guitar is tuned correctly. The dipole speaker as described here will handle notes down to about 80Hz.

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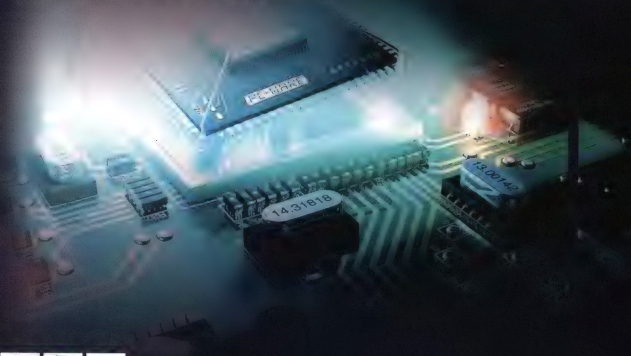

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WHITE NOISE GENERATOR

This white noise generator is very simple and cheap to build and produces white noise which does not repeat over any short time frame. It has a variety of uses, as explained below.

A **white noise signal** has equal intensity at all frequencies in the band of interest; for example, 20Hz-20kHz for audio. It's the hissing sound that you hear if you tune an analog FM radio to a frequency on which there is no transmission.

There are many reasons why you may want a white noise signal. For example, you can use white noise to drown out external noises that may interfere with your sleep. If that dripping tap is keeping you awake, don't count sheep; try a low-volume white noise source with a speaker close to your bed.

We can attest: it works wonders!

It's especially effective at helping babies get to sleep since they are used to hearing somewhat similar sounds in the womb. It can also be used to help treat (or at least mask) tinnitus (a persistent ringing sound heard in the ears when there is no sound present).

White noise sources can be used to measure the bandwidth or impulse response of a circuit and to check room acoustics or optimise a PA system.

They are also used in analog audio synthesisers to help produce the "sssh-hhh" sound of various percussion instruments such as hi-hats, snare drums and cymbals.

Generating white noise

There are several ways to generate white noise. For example, if you reverse-bias a zener diode or transistor emitter-base junction (ie, the base-emitter reversed) with a low DC current level, an AC voltage will appear across it and this will have a white noise characteristic.

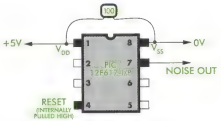


Fig.1: the "circuit" could hardly be simpler because everything is done in software within the PIC12F617-I/P. Noise output is taken from pin 7, while a 100nF capacitor bypasses the supply (pins 1 and 8) – pins 2, 3, 5 and 6 are not connected.

But the resulting AC voltage level is quite low and typically needs to be amplified by a factor of several hundred times to make it usable.

Alternatively, white noise can be generated digitally with a pseudo-random number generator.

This has the advantage that the signal level is already high, it is consistent and it is not dependent on a particular transistor or zener diode's characteristics.

National Semiconductor used to sell a digital noise source IC, the MM5837 (designed in the 1970s) that used an internal 17-bit pseudo-random sequence generator to produce white noise for audio applications. Supplied in an 8-pin DIL package, it was designed for musical instruments, synthesisers and for room acoustics testing.

Its main disadvantage was a noticeable cyclic repetition. The repetition was due to the full random sequence being produced in less than one second and being continuously cycled.

This IC is not available any more but with modern components, we can make an even better digital noise source.

An even better white noise source

Our design uses a low-cost 8-bit PIC12 microcontroller to produce a 31-bit pseudo-random sequence, which only repeats after 2^{31} or approximately two billion cycles. That works out to nearly eight hours so the repetition is definitely not discernible.

The basic "circuit" for our white noise generator is shown in Fig.1. IC1 is a PIC12F617-I/P which has a 2-5V supply fed into pins 1 and 8. A 100nF bypass capacitor is connected directly between pins 1 and 8 to ensure that it has a stable operating voltage. The noise output appears at its GP0 digital output (pin 7).

Pin 4 is the master clear/reset (MCLR) pin. This is held at VDD during normal operation by an internal pull-up current. If it is externally pulled low, this will hold the microcontroller in a reset state and so the noise output at pin 7 will cease. When released, the internal pull-up will bring it high again, allowing the processor to run and resuming noise generation.

You just need the two components, the programmed IC and a 100nF bypass capacitor, as shown in Fig.1.

And it's dead easy to wire up since only four pins are normally used – the bypass capacitor can be soldered right next to the IC (even right across pins 1 and 8 if you wish!). The other four pins (pins 2, 3, 5 and 6) are not used and should be left disconnected.

by John Clarke

While we are showing this as a mini "project" in its own right for those who need a dead simple white noise source, it will be quite familiar when you read the next project this month, the Steam Train Whistle project, because this is exactly what we used for the "steam" component.

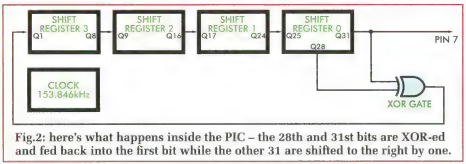


Fig.2: here's what happens inside the PIC – the 28th and 31st bits are XOR-ed and fed back into the first bit while the other 31 are shifted to the right by one.

Pseudo-random sequence generation

Fig.2 shows how the software generators a pseudo-random sequence generator using three 8-bit shift registers and a 7-bit shift register. The bits within the four shift registers labelled Q1 to Q31.

These bits are pre-loaded with a specific value when the micro comes out of reset, to provide a starting point for the random sequence; as explained below, this can be any state but all zeros.

Each time a clock pulse occurs, the value of Q1 is moved into Q2, Q2 into Q3 and so on, up to Q30 which is moved into Q31. This means that all the bit values are updated from their neighbour, except for Q1.

It gets its value instead from the output of a two-input exclusive-OR (XOR) gate, with its inputs being the values of bits Q28 and Q31.

Once this shifting is complete, the value of Q31 is effectively lost, although it does control the value loaded into Q1, so you can think of this as a modified type of "bit rotate" operation.

The Q31 bit value also determines the level on pin 7 and thus becomes the noise output; hence we do not want to retain its value in one of the other bits; if we did, this would quickly lead to repetition.

This approach has two advantages. One, the 31-bit length leads to a very long time until the sequence repeats and two, the simple XOR gate used to provide the pseudo-random effect is very easy to implement in software and takes very little time to process, allowing for a high clock rate and thus giving the noise signal a wide bandwidth.

The entire process to update the contents of the four registers, including the XOR operation, takes 13 software instructions.

The internal 8MHz oscillator of the PIC12 gives a 2MHz instruction rate (it takes four cycles to execute one instruction) and this results in a sampling rate of 153.846kHz (2MHz÷13).

When divided into the cycle length, this gives us the approximately eight-hour repeat rate mentioned earlier.

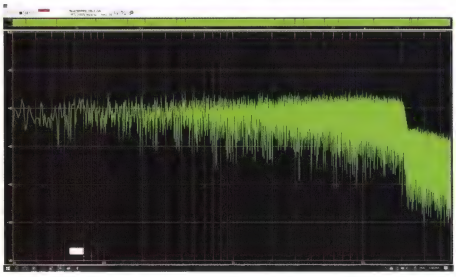


Fig.3: the spectrum of the white noise generated by the PIC. The power level is consistent across all frequencies up to about 20kHz. The drop in level discontinuity at 20kHz is due to sound card and computer software limitations.

The noise frequency distribution is therefore even up to about 76.923kHz, which is the Nyquist limit for this signal; ie, half the sampling rate.

Because the output is a square wave, it will have components at higher frequencies than this but they will have a decreased amplitude and power level.

The measured spectrum from our prototype is shown in Fig.3. It extends over the entire audio spectrum (20Hz-20kHz) and well beyond at both the low-frequency and high-frequency ends (the measurement bandwidth is only 20kHz).

While the IC generates white noise, it could potentially be used to generate pink noise with an appropriate filter at its output. But such a filter is not simple to design; it is something that we will cover in a future article.

Pink noise has its own uses, such as for calibrating audio equipment, simulating background noise and can also help with sleeping.

Ensuring a long repetition time

You may be wondering how we know that the sequence generated by this arrangement won't repeat for 2^{31} cycles.

That is guaranteed by using the correct "taps" (in this case, bits 28 and 31) to be combined to generate the new value of Q1 for each cycle.

The list of taps required for various length shift registers to ensure a maximum length repeat cycle is given on page 5 of the following application note: www.siliconchip.com.au/link/aakr

Note that this document refers to the use of an XNOR (exclusive NOR) gate rather than XOR gate. The only difference is with the lock-up state. That is the initial state of the shift registers where the generator stops producing a varying output.

The XNOR version has a lock-up state when all values in the shift registers are ones (high output), whereas the XOR has a lock-up state of all zeroes (all low).

The lock-up situation is prevented from happening when using either XOR or XNOR gates by starting the noise sequence with a number other than all zeroes or all ones. SC

Steam Train Whistle ... or Diesel Horn

It even has Doppler effect!

by JOHN CLARKE

Relive the exciting days of steam-train travel with this Steam Train Whistle or Diesel Horn sound generator. Use it in your model railway layout, as a doorbell or just as a standalone sound effect. It can even simulate the Doppler effect, providing a change in pitch as if the train is passing by. And the Whistle/Horn sound can even be customised in a number of ways, to suit your preferences.

Steam trains are always popular – many restored trains can be seen travelling the countryside on the weekends. Their popularity is proven by the crowds of people gathering to watch alongside the track and the number of people enjoying the ride.

Along with the chuff-chuff sounds of the steam engine, it is the whistle that gives the most excitement and nostalgia.

It is the toot of the whistle as the train departs; it is the sound of the whistle as it passes you by and the blast of the whistle as the train enters a tunnel or approaches a level crossing.

The great thing about this circuit is that you can get steam train sound without the corresponding sooty face!

Our device simulates a steam-powered whistle by mixing three separate oscillators with the output of a white noise generator.

These oscillators generate the whistle chimes, with plenty of harmonics to ensure they have a rich sound, while the noise generator provides the sound of the steam rushing out.

You can adjust the rise time of the volume at the start of the whistle. That simulates the rate at which the cord is pulled to open the steam valve to the whistle.

At the end of the whistle period, when the cord is released, the valve quickly shuts itself off

Features

- Produces steam whistle or diesel horn sound effects
- Steam simulation using white noise
- Adjustable volume rate rise for the steam whistle
- Multiple trigger options
- Adjustable whistle time
- Optional Doppler Effect
- Adjustable whistle frequencies

due to steam pressure (in our case, in 100ms).

If you elect to use Doppler Effect simulation, the situation is somewhat different. In this mode, the rise in volume simulates the train whistle starting from a distance away and then increasing in volume as it approaches nearer.

The decay in volume after the train passes (and after the frequency shifts) simulates the decrease in volume as the train moves away.

The Whistle/Horn sound can be initiated with a manual pushbutton, a microswitch, reed switch, relay or by a signal from an external microcontroller.

New design

The last Steam Train Whistle published in SILICON CHIP was in July 1994 and used mainly op amps for the oscillators and an amplifier for the noise source.

This new design includes many more features, including Doppler Effect, while using a much simpler circuit. That's because it is instead based around a low-cost microcontroller.

The basic concept is as follows. The micro generates three different pulse trains, each with a fixed duty cycle and adjustable frequency.

These pulse trains contain various frequencies including the fundamental and higher harmonics, which when mixed together, make a whistle or horn sound. When simulating a steam whistle, they are also mixed with white noise, as explained above.

The mixed sound is then fed to an audio amplifier with a built-in volume control circuit. The volume control signal comes from the same microcontroller which is producing the whistle/horn sounds. The amplifier then drives

5-chime and 3-chime steam whistles and diesel horns

The steam whistle featured in this article has three oscillators controlled by the microcontroller. This is ideal for simulating the sound of 3-chime steam whistles for NSWGR 30 and 59 class steam locomotives. However, most other NSWGR steam locomotives had 5-chime whistles, as did the locomotives in many other countries.

Clearly, we could have designed the circuit with five oscillators but that would have a required a microcontroller with more pins and more passive components. But since the simulated sound of this circuit is really quite convincing, we think this is a reasonable compromise.

If you want the exact whistle for a particular locomotive, it would better to use our sound effects module (featured elsewhere in this issue) together with correct WAV stored on its microSD card.

These comments also apply to diesel locomotive horns. Some large diesel locomotives have five chime horns but many did have 3-chime or even 2-chime units.

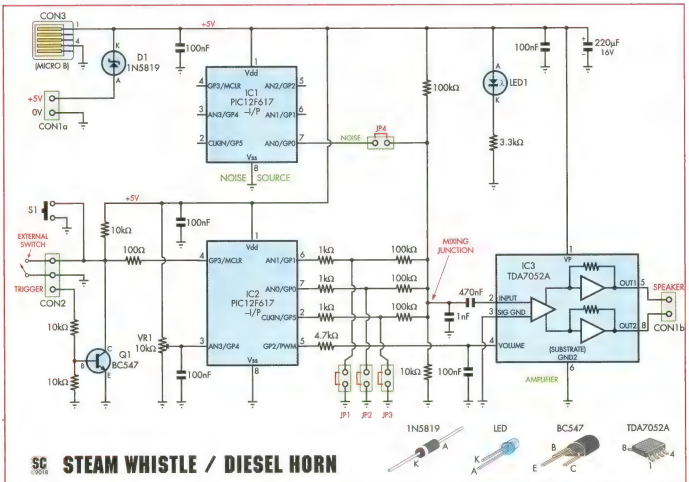


Fig.1: IC1 produces white noise which is used to emulate steam sounds, while IC2 produces three pulse trains which are mixed together to give a whistle or horn sound. This signal is then fed to amplifier IC3 which drives the speaker. It is powered from a 5V DC or USB supply and the sound is triggered by onboard switch S1 or an external switch or signal via CON2.

Specifications

- Power supply: 5V at 300mA from an external supply via screw terminals or USB cable
- Output power: about 1W into 8Ω
- Regular whistle period: 100ms to 22.5s, extended if S1 held down (no Doppler Effect) 2.5s to 22.5s, no extension (with Doppler Effect)
- Whistle volume rise time: 5ms to 8s
- Whistle volume fall time: 100ms fixed (no Doppler Effect 5ms to 8s (with Doppler Effect)
- Whistle frequency range: 244Hz to 1.053kHz
- Frequency adjustment steps: 3Hz at 250Hz, 6Hz at 333Hz, 12Hz at 500Hz, 24Hz at 666Hz, 48Hz at 1kHz
- Simulated speed for Doppler Effect: 80km/h

a speaker to produce the final sound.

The length of the Whistle/Horn sound can be adjusted. If set to minimum, the whistle sound will only be for as long as the trigger switch is closed.

Or it can be set to a longer time so that a brief press of the switch will initiate the sound for a fixed period.

Depending on the mode, holding the switch down may or may not extend the sound beyond this set period

Circuit description

The circuit is shown in Fig.2 and comprises three ICs: two PIC12F617 microcontrollers (IC1 and IC2) and a TDA7052A 1W Bridge-Tied-Load (BTL) mono audio amplifier with DC volume control (IC3).

IC1 is the white noise source and runs an internal program that generates noise over the full audio spectrum. You'll find a full description of its operation in the "White Noise Generator" project elsewhere in this issue.

It's designed so that it can be re-used in other circuits where a white noise source may be required.

For now, all you need to know is that a white noise "hissing" audio signal is produced at its pin 7 output.

This noise signal is fed to the audio mixing point, at the junction of the 10kΩ resistor and 100kΩ resistor, via JP4, which can be used to disconnect the white noise source when simulating a diesel horn or while adjusting the oscillator frequencies.

IC2 produces the whistle and horn sounds. It does this using three pulse trains from its GP1, GP0 and GP5 digital outputs (pins 6, 7 and 2).

It also produces a DC control signal by filtering a PWM signal which is produced at pin 5. This is fed to the volume control input on amplifier IC3 and this is used as an "envelope" for the whistle and horn sounds.

IC2 also monitors an external switch via its GP3 input (pin 4, which is used to trigger the sound effects. And it reads the wiper position of trimpot VR1 using its AN3 analog input (pin 3), which controls various options such as the component frequencies of the whistle/horn sound, the whistle/horn time and the volume rise rate for the steam whistle.

The pulse trains from the GP1, GP0 and GP5 outputs are fed to an audio mixing point, at the junction of the 100kΩ and 10kΩ resistors, via a 1kΩ series resistor for each output.

The pulse trains from those three outputs are not quite square waves; a square wave has a duty cycle of 50% while the pulses from these outputs have a duty cycle of 43.75%.

This provides a richer set of harmonics than a square wave. A square wave has only odd harmonics whereas this series of slightly shorter pulses also has even harmonics.

This produces a more realistic sound.

The supersonic harmonics of the mixed signal are filtered out by a 1nF capacitor to ground and the audio signal is then AC-coupled to input pin 2 of audio amplifier IC3 via a 470nF capacitor. This drives the speaker connected to CON1 in bridge mode.

This chip has a volume control input on pin 4. A DC voltage is applied to this pin and the higher the voltage, the louder the output volume.

This volume control signal is produced by microcontroller IC1 using filtered PWM, from its pin 5 PWM output. The 4.7kΩ resistor and 100nF capacitor form an RC low-pass filter with a -3dB point of 339Hz.

The actual PWM frequency is 19.61kHz, which is so much higher than the filter corner frequency that the output of the filter is effectively a DC voltage, proportional to the PWM duty cycle.

Initially, the pin 5 output is low, setting the attenuation in IC3 to its maximum value of more than -70dB, which mutes the audio output. The PWM pulse width is gradually increased to bring the average voltage at pin 4 up to 1V, resulting in an eventual amplifier gain of +20dB.

The steam whistle/horn sound effect is triggered by pressing pushbutton S1 to pull the GP3 input (pin 4 of IC1) low. It is normally held high by a 10kΩ resistor to the 5V rail.

You can also use an external switch

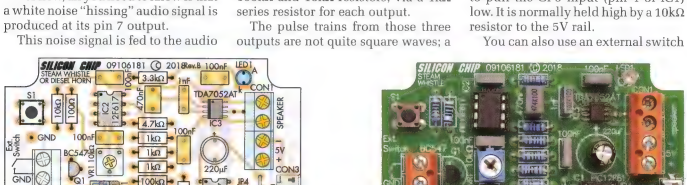


Fig.2: use this PCB overlay diagram and matching photo as a guide for building the Steam Whistle / Diesel Horn board. IC3 and CON3 are the only SMD components. Take care when soldering CON3 since the pins are small and close together, and easy to bridge. Don't get IC1 and IC2 mixed up; while they are the same type of chip, they are programmed with different firmware.

between pins 1 and 2 of CON2 (which could be a set of relay contacts) or by applying at least 1.5V between pins 2 and 3 of CON2, which switches on NPN transistor Q1, pulling the GP3 input low.

The circuit is powered from 5V, either applied to part of terminal block CON1 or via a micro type-B USB connector, CON3.

When using CON1, diode D1 provides reverse polarity protection. The supply is bypassed using a 220µF capacitor and several 100nF capacitors, one for each IC.

Changing the sound

Jumper shunts JP1-JP3 allow the frequencies of these pulse trains to be adjusted. Two of these jumpers are inserted at a time, shorting two of the pulse trains to ground and thus disabling them. This allows you to measure the frequency of the third pulse train and make adjustments using VR1. Pressing pushbutton S1 then saves the new frequency setting to EEPROM.

Microcontroller IC2 detects whether any of the jumpers are inserted at start-up by enabling internal pull-up currents for the three output pins and then sensing whether any of them are held at ground potential.

If so, it goes into adjustment mode. If none of the jumpers are present, all three outputs will be high and the software goes into the normal sound effects generation mode.

A similar method is used to adjust the initial volume ramp rate for the horn/whistle. This is done by inserting all three shunts, rotating VR1 and then pressing S1 to store the new ramp time.

Trimpot VR1 connects across the 5V supply and so its wiper voltage sweeps from 0V to 5V as its screw is rotated clockwise.

This voltage is applied to the AN3 analog input of IC2 and converted to a number using its internal analog-to-digital convert (ADC). It is used to set the pulse train frequencies and initial volume ramp rate as described above

Construction

The Steam Train Whistle is built on a double-sided PCB coded 09106181, measuring 79 x 48mm. It can be housed in a UB3 plastic utility box if desired.

The overlay diagram, Fig.2, shows where the parts are fitted. Install SMD IC3 first as it is easier to solder the pins when there are no components surrounding it.

You will need a fine-tipped soldering iron and 0.7mm diameter solder.

First, align the IC pins onto the pads making sure the that chamfered side of the chip is positioned towards the pin 1 indicator on the board, as shown in Fig.2. Tack solder one of the outside pins to its pad and check that the IC alignment is correct. Re-melt the solder and realign if necessary. Then solder the remaining pins. Make sure you refresh the solder on the first pin at the end.

If you accidentally bridge two pins, the excess solder can be removed with a dab of flux paste and some solder wick.

The micro type-B USB connector is soldered in a similar manner to IC3. Align the leads to the pads and solder the two outer flanges on the sides of the USB housing first, followed by the five pins.

Clear any pins that are shorted with solder wick.

The resistors should be fitted now and these are colour coded, as shown below. But you should use a digital multimeter to check the values of each resistor before soldering it as the colour codes can be mistaken.

Mount diode D1 next, with the striped end (cathode) oriented as shown in the overlay diagram.

We recommend using an IC socket for ICs1&2. Take care with orientation when installing the sockets – use Fig.3 as a guide.

Now fit headers for jumpers JP1-JP4 and the PC stake at the GND position. Follow with the capacitors, starting with the smaller MKTs and then the 220µF electrolytic capacitor. This

Parts list – Steam Whistle/Diesel Horn

1 double-sided PCB, coded 09106181, 79 x 48mm
2 2-way screw terminals with 5.08mm pin spacing (CON1)
1 3-way screw terminal with 5.08mm pin spacing (CON2)
1 8Ω 1W loudspeaker [eg, Jaycar AS3030 or AS3004, Altronics C0603C]
1 PCB-mounting micro type-B USB socket (CON3) [Altronics P1309, Jaycar PS0922]
2 8-pin DIL IC sockets (for IC1,IC2)
1 momentary pushbutton switch (S1) [Altronics S1120, Jaycar SP0600]
4 2-way headers with 2.54mm spacings with shorting blocks (JP1-JP4)
1 PC stake

Semiconductors
1 PIC12F617-I/P programmed with 0910618A.HEX (IC1)
1 PIC12F617-I/P programmed with 0910618M.HEX (IC2)
1 TDA7052AT/N2 1W BTL DC volume control amplifier (IC3) [Cat SC3551]
1 BC547 NPN transistor (Q1)
1 1N5819 1A schottky diode (D1)
1 3mm LED (LED1)

Capacitors
1 220µF 16V PC electrolytic
1 470nF 63V or 100V MKT polyester
5 100nF 63V or 100V MKT polyester
1 1nF 63V or 100V MKT polyester

Resistors (all 1%, 0.25W)
4 100k 4 10kΩ 1 4.7kΩ 1 3.3kΩ 3 1kΩ 1 100Ω
1 10kΩ mini horizontal trimpot, code 103 (3386F style) (VR1)

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	4	100kΩ	brown black yellow brown	brown black black orange brown
❑	4	10kΩ	brown black orange brown	brown black black red brown
❑	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	1	3.3kΩ	orange orange red brown	orange orange black brown brown
❑	3	1kΩ	brown black red brown	brown black black brown brown
❑	1	100Ω	brown black brown brown	brown black black black brown

Changing the whistle or horn sound

Changing the whistle period

With no jumpers inserted for JP1-JP3, rotate VR1 to adjust the whistle period, up to a maximum of 22.5s (fully clockwise).

If you are not using the simulated Doppler Effect, the whistle period can be extended indefinitely by holding down S1.

Changing the volume rise rate and Doppler effect

This applies to the steam whistle sound only (ie, not the diesel horn). Switch off power and insert jumper shunts for JP1, JP2 and JP3. Power up and set VR1 for the desired ramp time, with a more clockwise position selecting a longer ramp.

To disable the Doppler Effect, set VR1 to a position between fully anti-clockwise and halfway.

With VR1 fully anti-clockwise, the initial volume ramp-up is almost instant, while if you set it just slightly less than its midpoint, you will get a ramp-up time of around eight seconds. Intermediate settings give a shorter ramp-up time.

To enable the Doppler Effect, set VR1 to a position between halfway and fully clockwise. The ramp setting is similar, ie, just above halfway will give you an almost instantaneous ramp-up while setting VR1 fully clockwise sets the ramp-up time to around eight settings.

In this mode, there is also a volume ramp-down period at the end of the effect and it is the same time as the ramp-up.

When VR1 is set at the required position, press S1 so that the setting is stored in flash memory.

Switch off power and remove the three jumper shunts. Set VR1 back to the required position for the whistle period when you've finished. You can then power it back up and press S1 to test the new setting.

Note that it's generally a good idea to set the whistle period in Doppler Mode to be slightly longer than twice the ramp-up/ramp-down time. This way, the volume will rise to maximum and then almost immediately begin to fall again, as if the train has just passed.

You may need to tweak the volume rate and whistle period a few times to get the desired effect.

Changing the oscillator frequencies

The table below shows some suggested sets of oscillator frequencies to simulate a steam whistle and various diesel horns but note that you are not restricted to just using these frequencies.

The first entry shown gives the frequencies that the unit will default to the first time it is powered up.

The oscillator frequencies are changed one at a time. Start by switching off power and then place two jumper shunts on JP1-JP3, leaving out the jumper in the channel that you want to adjust. Remove JP4 to disable steam noise for the moment.

Now attach a frequency meter (eg, a DMM with frequency measurement) to the right-most pin on the unused jumper header.

Connect its ground reference to the ground PC stake (between S1 and CON2).

Apply power and adjust VR1 until your meter reads the frequency required. It can be adjusted over the range of 244-1053Hz. The frequency will change in steps of 3Hz at the low end, rising to 48Hz at the high end.

You will be able to hear the oscillator if the speaker is connected. When you have settled on the required frequency, press S1 to store the value in flash memory.

To adjust another oscillator, disconnect power and move one of the jumper shunts, then re-apply power and go through the same procedure again.

When you have finished, switch off and remove JP1-JP3. Re-install JP4 if you removed it earlier.

Set VR1 back to the required position for the whistle period now that you have finished adjusting the oscillator frequencies.

Sound effect	Oscillator 1	Oscillator 2	Oscillator 3	White noise
Steam whistle (default)	740Hz	525Hz	420Hz	Yes (JP4 in)
2-Car Diesel	600Hz	520Hz	420Hz	No (JP4 out)
40-43, 4401-4440 Diesel	277Hz	329Hz	440Hz	No (JP4 out)
422, 442, 73, 48126 Diesel	548Hz	322Hz	429Hz	No (JP4 out)

Suggested oscillator frequencies for various whistles or horns.

capacitor is polarised and must be installed with the polarity shown, with the longer lead through the hole marked "+" (the striped side is negative).

Install transistor Q1, switch S1 and trimpot VR1. Then you can mount terminal blocks CON1 and CON2. CON1 comprises two dovetailed 2-way screw connectors and CON2 is a 3-way screw connector.

Ensure that all the terminal blocks are fitted with the wire entry holes to the outside edge of the PCB.

Finally, LED1 can be soldered in place. We mounted it with the plastic lens 15mm above the PCB so that it would protrude through the lid of the UB3 Jiffy box but you could mount it at a different height if necessary. Fit it with the longer anode lead soldered to the pad marked "A" on the PCB.

Although shown as a bare board, the Steam Train Whistle can be installed in a UB3 box. The PCB clips it into the moulded side rails on the inside of the box.

Cutouts can then be made in the ends of the box for the USB connector and the wires going to screw terminals CON1 and CON2. The loudspeaker is ideally mounted in a small box so that it has a good bass response.

Testing

With IC1 and IC2 out of their sockets, apply power either via a 5V DC supply connected to CON1, or using a USB cable from a computer or USB supply.

Check that LED1 lights up and that there is around 5V between pins 1 and 8 of the sockets for IC1 and IC2. If power is applied to CON1, the reading will probably be closer to 4.7V due to diode D1.

Regardless, you should get a reading between 4.5V and 5.25V. You can then remove power from the circuit.

If you have purchased pre-programmed microcontrollers then you can plug IC1 and IC2 into their sockets now, making sure that they are oriented correctly and that the correct programmed IC is in the correct socket. The chip programmed as the noise generator is IC1.

If your chips have not already been programmed, you will need to program them first, using HEX files downloaded from the Silicon Chip website.

There are two different files for IC1 and IC2.

Connect the speaker to CON1 and apply power again. Set VR1 fully anticlockwise and press and hold S1. You should be greeted by the steam train whistle sound.

If you don't hear the steam noise in the background, check that JP4 has been inserted.

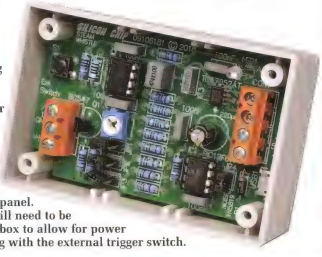
Installation

The board is too large to mount inside a locomotive so if you want to use it as part of a model railway layout, the best place to put it would be underneath the layout, for example, near a station.

You could then mount the speaker inside the station. It could be triggered manually or via a reed switch or microswitch as the train passes.

Whatever kind of switch you are using, connect it between pins 1 and 2 of CON2.

Or if you are using a microcontroller to trigger it, connect a digital output pin on that micro to pin 3 of CON2 with the micro's ground going to pin 2. You can apply anywhere between 1.5V and 12V to this pin to trigger the unit.



Assuming you're building this for a model train layout, the PCB can be mounted "as-is" wherever there is a suitable place on or in your layout. But it is also designed to clip into the side rails of a UB3 Jiffy box, as shown here, with the LED just poking through the front panel. Naturally, access holes will need to be drilled in the ends of the box to allow for power and speaker wiring, along with the external trigger switch.

The Doppler Effect

The Doppler Effect refers to the fact that when an object is moving towards you, any sound that it generates will appear to be higher in pitch than usual. And similarly, if that object is moving away from you, the sound will appear to be lower in pitch. For example, it is very obvious when a vehicle with a siren passes you at high speed.

It happens because sound waves travel through the air at approximately 340m/s (1200km/h) and as the speed of the generating object (relative to you) becomes a significant fraction of that, the sound waves pass you at a noticeably different rate, thus altering the perceived pitch.

If you are interested in finding out more about the Doppler Effect, see https://en.wikipedia.org/wiki/Doppler_effect

Since trains can travel quite fast, the Doppler Effect can be very apparent, especially when they use their whistle or horn as they are passing you. At 80km/h, the pitch changes by about 6.5% in each direction and the overall 13% difference is very noticeable. So we have included a facility to simulate this. SC

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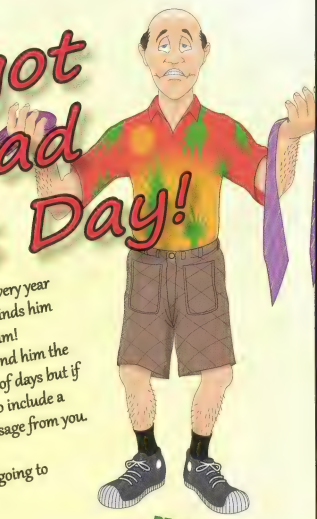

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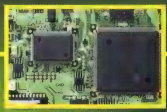

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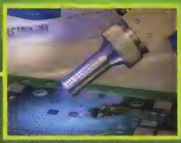

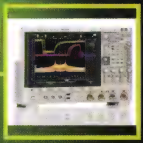

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Showcasing New Technology in Electronics

Australia's only dedicated trade event for the electronics industry will this year be held in Sydney in September.

ElectroneX – The Electronics Design and Assembly Expo will be staged from 5 – 6 September at Rosehill Gardens Event Centre.

The expo is now in its 9th year and alternates annually between Sydney and Melbourne.

With over 90 exhibitors and a technical conference plus free seminars featuring leading international and local industry experts, this is a must see event for decision makers, enthusiasts and engineers designing or working with electronics.

Attendees can pre-register for free at www.electronex.com.au

This year's event will feature a host of new product releases as well as advanced manufacturing solutions as Australian companies embrace the move towards niche and specialised manufacturing applications.

In recent years there has been a resurgence of companies sourcing products and solutions from Australian based suppliers as local manufacturers seek out specialist applications and recognise their expertise and quality control.

The last event in Sydney in 2016 attracted over 1200 electronics design professionals including electronic and electrical engineers, technicians and management, along with OEM, scientific, IT and communications professionals, defence, government and service technicians.

SMCBA Conference

Since 1988 the SMCBA has conducted Australia's only conference dedicated to electronics design and manufacture.

The 2018 conference, an initiative of the SMCBA, will again be held as part of ElectroneX, which gives the electronics industry a dedicated exhibition and conference in one place. Since the first staging of the ElectroneX event in 2010 the number of exhibitors has increased threefold.

Andrew Pollock, Executive Officer of the SMCBA since 1996 said "We are delighted that Susy Webb and Jasbir Bath, both from the US, have accepted our invitations to present workshops at the conference in 2018. They bring a wealth of electronics design and manufacturing knowledge which they will generously share with attendees."

In addition, the most popular IPC training and certification program, the IPC-A-610 Acceptability of Electronics Assembly course

will be conducted by one of the SMCBA's Master IPC Trainers.

The IPC-A-610 is the most widely used document in the electronics industry worldwide and the SMCBA has been conducting these programs for over 20 years.

Susy Webb is a senior PCB designer with 37 years of experience. Her career includes experience in coastal and oceanographic oil exploration and monitoring equipment, point-to-point microwave network systems, and CPCI and ATX computer motherboards.

She has set up standards, documentation, procedures, and library conventions for several companies.

Webb is a regular speaker at the PCB, IPC and international Design conferences, and consults for individual companies as well. Her presentations discuss practical implementation of complex engineering concepts into board layout, and methods to improve the overall design and flow of printed circuit boards.

She is CID certified and a former writer/columnist for Printed Circuit Design and Fab magazine.

Webb is also an active member of the IPC Designer's Council Executive Board and Education Committee, and is a member and past president of the Houston Chapter of the IPC Designer's Council.

Susy's workshops will be:

- Designing Beyond Simulation
- Building a Bridge from Design to Manufacturing
- The Complexities of Designing with Fine Pitch BGAs
- Part Placement Choices and Consequences

Jasbir Bath has over 20 years of experience in research, design, development and implementation in the areas of soldering, surface mount and packaging technologies.

He has extensive knowledge of soldering technologies and in 2012 was appointed as principal engineer within IPC's assembly technology area.

He began his engineering career as a technical office at the International Tin Research Institute (ITRI) in the UK.

In 1998 he joined Flextronics/Solectron as a lead engineer specialising in soldering materials, processes and components. In 2008 he formed his own company providing process consulting and training services to he electronics manufacturing industry.

Jasbir has contributed to four books on lead-free manufacturing and has worked closely with IPC's Solder Products Value Council (SPVC) to develop process and reliability data and he served on an IPC Blue Ribbon Committee to develop the IPC Lead-free Process Certification Site Audit Program.

He holds BS and MS degrees in materials science from the University of Manchester England.

Jasbir's workshops will cover:

- Design for manufacturability and reliability
- Printing and Its effect on manufacturing yield
- Reflow, wave and rework soldering process optimisation in electronics manufacturing

It would not be possible to bring international experts to Australia for the conference without the support of the ElectroneX sponsors:

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For full details please visit www.smcba.asn.au/conference

New Lead Free 100W Touchscreen Soldering Station

Altronic Distributors (Stand A2) is introducing the T 2460A high-power temperature controlled soldering station with touchscreen.

This soldering station incorporates a special intelligent microchip control design. It has been developed to meet the present and future lead-free soldering needs of the electronic assembly industry and is suitable for work on SMD electronics. The ergonomic handle with a short distance between heating element and tip allows very fast heat up time and quick heat dispersion. The sensor and heat transfer technology employed ensures precise temperature regulation required for making consistent, reliable soldering connections. The temperature is maintained within ±3°C.

Also on display will be their range of Australian-approved and certified "Powertran" toroidal transformers, which are available in various voltage and current ratings from 30VA to 500VA.

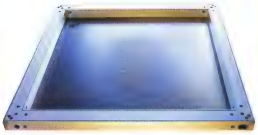
For further information and assistance visit the Altronics stand at ElectroneX or call Altronic Distributors on 1300 780 999; email sydneywholesale@altronics.com.au or refer to their web site www.altronics.com.au

Emona's 3D Printed Electronics

Emona Instruments, stand B1, is bringing high-technology electronics 3D printing solutions to Australian industry for electronics R&D, manufacturing, research and education with the printing of multi-layer PCBs, as well as resistors, capacitors, antennas, sensors and thin film transistors.

Emona's multi-layer PCB 3D printing solution is provided by Nano-Dimension's DragonFly 2020 Pro. This brings together an extremely precise inkjet deposition printer, high performance silver nano-particle conductive and dielectric inks as well as dedicated software, enabling companies to bring designs to the market more quickly, while keeping sensitive design information in-house.

Emona's 3D printing of electronics is provided by US based Optomec Inc's Aerosol Jet technology. Electronic components such as resistors, capacitors, antennas, sensors and thin film transistors have all been printed with Aerosol Jet technology. The performance parameters of printed components, for example the ohm value of a resistor, can be controlled through printing parameters. Components can also be printed onto 3-dimensional surfaces eliminating the need for a separate substrate thereby reducing the size, thickness and weight of the end product. For example, Aerosol Jet is used to print antennas and sensors that conform to the shape of the underlying substrate such as a cell phone case. The Aerosol Jet process supports printing on a wide variety of substrates including plastics, ceramics and metallic structures.



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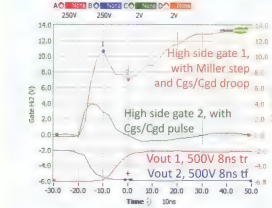

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HK Wentworth Showcase New Hakko Soldering Products at Electronex Aust

HK Wentworth, sole authorised wholesale distributor for Hakko soldering solutions in Australia will be showcasing some new Hakko products alongside their Electrolube electro-chemical solutions at Electronex Australia later this year. Experts from both Hakko and Electrolube will be available on Stand A16 (Sydney, September 5-6 2018) to assist with customer application queries.

The first of the new Hakko soldering solutions is the **FX-801** Ultra Heavy Duty (UHD) Soldering Station, an ideal soldering station for extremely large mass components, such as high current inductor coils, heat sinks, large transformers, shields, and other difficult solder applications, where there is a significant amount of thermal inertia to overcome.

The ESD safe FX-801 soldering station enables effortless soldering of the even the most challenging solder joints. This Ultra Heavy Duty Soldering Station provides the ultimate heating performance with a super power 300W composite heater for the highest level of soldering efficiency. The lightweight soldering iron is only 50g and the system has six user programmable preset

temperatures, process control lockout with password protection and a large LED display.

The second new product for Electronex is the FX-100 RF Induction Heating Soldering System. Designed for fast, reliable, accurate, efficient and ESD safe soldering, the FX-100 delivers RF induction heat technology at its best.

For ease of use, calibration is not required, just power up and the system is ready for use. A boost control delivers an injection of extra power to the soldering iron tip when required. The compact design also minimises the workbench footprint and a tip sleep function reduces the tip temperature to preserve the life of the tip and reduce oxidization when the iron is not in use. There is also an activity monitor that provides cumulative data on tip heater loads and tip running time to aid in process control and manage operating costs.

With over 60 years' experience in soldering technology, Hakko has been producing superior quality soldering and desoldering tools, hot air rework stations, smoke and fume extraction systems, technical training classes, and a wide assortment of accessories and related equipment for the electronics, industrial and hobby industries.

Mike Woods, HK Wentworth's Australia and New Zealand Sales and Marketing Manager commented, "The new products from Hakko are welcome additions and are expected to create a lot of interest at the show. I'd like to extend an open invitation to visitors to come along to stand A16, where they will be assured of a warm welcome and lots of free advice on how to make best use of the company's entire soldering product portfolio.

For further information, please visit HK Wentworth's website: www.hakkoaustralia.com/ to download brochures of Hakko products.

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Streamline Series USB Platform offers advanced capabilities with zero compromises

The new Keysight Streamline Series comprises compact USB instruments: vector network analysers (VNAs), oscilloscopes and an arbitrary waveform generator (AWG) that incorporate Keysight technologies, measurement algorithms, and application software.

Controlled via PC through a USB connection, Keysight's new instruments help customers save space on the test bench and are easily shared among members of a development team.

The small rack size makes them ideal for manual or semi-automated testing in design-validation and light-manufacturing applications.

Keysight Streamline Series platform is available in three models:

- The P937xA models are compact two-port VNAs with frequency coverage up to 26.5GHz. All are designed to test passive devices such as antennas, filters and duplexers. Running on a host PC, the context-sensitive user interface is identical to that of Keysight's latest benchtop VNAs.
- The P924xA high-performance oscilloscopes provide full measurement functionality along with advanced triggering, rapid waveform updates and popular features such as zone triggering. With the Keysight InfiniiVision interface running on the user's PC, the look and feel is consistent with familiar benchtop oscilloscopes.
- The P9336A three-channel AWG provides 16-bit resolution with maximum bandwidth of 540MHz and maximum onboard memory of 4 GB.

Applications range from general-purpose testing to complex I/Q signal generation for characterization of transceivers and modulators.

If you can't get to ElectroneX (stand B27), more information about Keysight Streamline Series instruments is available at www.keysight.com/find/streamline

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If you're looking for efficient and reliable manufacturing, *LEACH can provide a high-quality product at the right cost.*

Want to be assured that the product has zero defects? *LEACH will test every item before shipment.*

Need someone to provide the required logistics for global distribution? *LEACH will take on this task.*

LEACH has extensive experience in producing boards for customers in communications, transportation, instrumentation, networking, energy, Industrial equipment, medical devices and more: 1-14 layers mass production. 0402, 0603, 0805, 1210, 2512, QFP (0.3mm spacing), BGA (0.5mm spacing), IC (0.3mm spacing). RoHS process as standard.

You can discuss your requirements with the experts from LEACH at ElectroneX – you'll find them on stand D29.

Keysight Streamline Series USB Instruments

Compact form. Zero compromise.

OSCILLOSCOPE

Up to 1 GHz bandwidth

2 analog channels, 5 GSa/s

1,000,000 wfm/s update rate

Zone triggering, 6-in-1 instruments, other apps

VNA

Wide frequency range: up to 26.5 GHz

Full 2-port VNA

Ability to extend number of ports

AWG

Three different 540 MHz channels

Up to 1 GHz IQ baseband bandwidth

Precise channel-to-channel synchronization

www.keysight.com/find/streamline

KEYSIGHT TECHNOLOGIES

ElectroneX

Stand B27

Come and see Cleverscope's VERY clever "scope" – CS448 – at ElectroneX

Cleverscope will be demonstrating their CS448 four-channel PC-based isolated oscilloscope at ElectroneX 2018 in Sydney. The design work for this new product took more than five years. The result is a scope with outstanding performance.

It's designed for challenging applications such as probing high-voltage, high-frequency variable speed drives which involve very fast common mode voltage rise and fall rates. This sort of application requires a scope with multiple isolated channels, wide bandwidth, high precision and low capacitance.

The high precision is especially important for accurately measuring current flowing through very low value shunts in high-power devices.

The CS448 uses 14-bit analog-to-digital converters (ADCs) with very low noise, which give a resolution of 0.1V on the 800V range. Its high precision means an error of less than 1% when measuring current in a sense resistor with a common mode voltage slewing 680V in 10ns. Channel capacitance is under 10pF to minimise common-mode capacitive current when probing high-voltage switching systems.

The CS448 uses high-bandwidth digital fibre-optic isolators to provide 1000V isolation between channels, and between each channel and the controlling PC. It also uses a carefully crafted isolated power supply and shielded digital circuitry, to keep noise injection into the scope front end to a bare minimum.

The common-mode rejection ratio (CMRR) exceeds 100dB up to 65MHz; an outstanding result. That means less than 2mV of common-mode signal injection for a common mode voltage swing of 680V in 10ns! That's for a 1:1 probe; it's still a modest 20mV when using a 10:1 probe.

The CS448 also incorporates a low-jitter clock system to keep measurements synchronised. This also allows multiple scopes to be synchronised, as a way to expand the number of available channels. Extremely low jitter in the clocks allows full advantage to be taken of the 14-bit ADC resolution.

Come see us and have a chat to the designer, Bart Schroder, at stand A13 at the ElectroneX show.

New Electrolube resins on display at the HK Wentworth Stand (A16)

Electrolube, distributed in Australia by HK Wentworth, will showcase some specialist encapsulation resin systems and thermal management materials for Australia's LED manufacturers at this year's ElectroneX.

New products on show will include ER2224, which provides high thermal conductivity and excellent thermal cycling performance, making it ideal for use in LED lighting units where it helps to promote heat dissipation and prolong unit service life.

The thermally conductive epoxy resin system offers an improved method of cure and subsequent health and safety benefits for the user.

The tough new UR5638 polyurethane resin provides a clear, transparent finish and is a low exothermic resin, making it ideal for LED applications involving the encapsulation of larger LED lighting units.

As an aliphatic polymer, the resin also offers superior UV stability as well as excellent transmission of visible light, making it an excellent resin for white light LEDs.

ELECTROLUBE
THE SOLUTIONS PEOPLE

Mastercut Stencils using Datum Tension shim Technologies

ElectroneX Sydney Stand A27

Mastercut Technologies are pleased to announce the availability of solder paste stencils made from the revolutionary Datum Tension shim material.

Datum claim their new material provides equivalent or better stencil cutting and print yield results than Fine Grain stainless steel but at a significantly lower cost.

The higher tensile strength improves registration in fine pitch stencils while offering better release characteristics for fewer cleaning cycles and downtime.

Mastercut's Director of Marketing, Bill Dennis says "Trials with existing customers have proven the benefits of Datum Tension and we are happy to offer it alongside our conventional 304 shim."

"It costs a little more but the quality and performance far outweigh the price difference" he goes on to say that "experience has shown that the perfect end-product starts with a high quality stencil"

Mastercut will be exhibiting again at Electronex in Sydney.

Oscilloscope innovation. Measurement confidence.

Find the ideal Rohde & Schwarz tool for your application:

www.rohde-schwarz.com/oscilloscopes

sales.australia@rohde-schwarz.com

Visit us at Electronex Sydney
Stand A12
5 - 6 September 2018

ROHDE&SCHWARZ

PRODUCT SHOWCASE

Temperature Shock Tests, ShockEvent Test Cabinets from Simultech Australia

Environmental conditions have a great effect on the functionality and reliability of electronic components, devices and systems.

In order to discover latent weaknesses in the shortest possible time, a typical temperature test is often insufficient; test specimens must be subjected to multiple, abrupt temperature changes.

With Simultech's temperature shock test cabinet, extremely rapid temperature changes in the range from -80°C to +220°C can be implemented.

Contact:
Simultech Australia Pty Ltd
Industrial Park, 21 Chris Drive,
Lilydale Vic 3140
Tel: (03) 9735 9816
Web: www.simultech.com.au

This allows you to reduce the incidence of early failures and increase the reliability of your products – reproducible, certified and in time lapse.

Simultech's Environmental Simulation Chambers and Systems are available under the brand names "weisstechnik" and "vötschtechnik". Product highlights include:

- New, eco-friendly refrigerant R449A
- Web-based user interface WEBSeason

Create secured IoT endpoints with 32-bit MCU featuring chip-level security

With the tremendous growth of IoT nodes, security has become an afterthought for many designers, increasing the risk of exposing intellectual property (IP) and sensitive information.

Fortunately, the newly launched SAM L10 and SAM L11 MCU families from Microchip can help designers plan for security at an early stage with Arm TrustZone for Armv8-M, a programmable environment that provides hardware isolation between certified libraries, IP and application code.

These MCUs, based on the Arm Cortex-M23 core, feature chip-level tamper resistance, secure boot and secure key storage that, when combined with TrustZone technology, protect customer applications from both remote and physical attacks.

The SAM L11 family also includes an on-board cryptographic module supporting Advanced Encryption Standard (AES), Galois Counter Mode (GCM), Secure Hash Algorithm (SHA), as well as a secure bootloader for secure firmware upgrades.

Both MCU families offer Microchip's latest generation Peripheral Touch Controller (PTC) for capacitive touch capability with best-in-class water tolerance and noise immunity, making the devices ideal for a myriad of automotive, appliance, medical and consumer Human Machine Interface (HMI) applications.

In addition, they provide industry-leading power consumption in active and all sleep modes with Microchip's proprietary picoPower technology. The SAM L10 received a ULPMark score of 405, which is over 200% better performance than the nearest competitor certified by EEMBC. A power debugger and data analyser tool is available to monitor and analyse power consumption in real-time and fine tune the consumption numbers on-the-fly to meet application needs.

Contact:
Microchip Technology Inc
Unit 32, 41 Rawson St Epping NSW 2121
Tel: (02) 9868 6733
Website: www.microchip.com

NSW Government backs Digital prescription app

Patients will soon be able to receive medical prescriptions from their doctor via a world-first smartphone app being developed by start-up company ScalaMed, with support from the NSW Government.

John Barilaro, Deputy Premier, Minister for Small Business, Skills and Regional NSW said ScalaMed has received a $25,000 Minimum Viable Product grant from the NSW Government-backed "Jobs for NSW" to develop the app. This grant supports startups that are yet to generate revenue to create innovative solutions that address industry needs or market gaps.

When implemented, patients will be able to download the ScalaMed app and add their doctor to receive prescriptions straight to their mobiles, including information on their medication and how to use it. It will also provide digital record keeping for patients, doctors and pharmacists.

ScalaMed founder Dr Tal Rapke, who has worked in medical wards for 20 years, said his next generation prescription system represents the future of healthcare. "ScalaMed won't replace the need to go to a doctor," he said.

"Rather, it is the first step in creating consumer-centered healthcare where we can take the hassle out of managing prescriptions. This system aims to streamline the prescription system and provide efficient digital record-keeping to benefit patients, healthcare professionals and pharmacists."

ScalaMed is looking to roll out the app in Australia and the US and will use blockchain technology to ensure data security and artificial intelligence to support patients being treated.

Contact:
NSW Dept of Industry
GPO Box 5477 Sydney NSW 2001
Tel: (02) 9338 6600
Website: www.industry.nsw.gov.au

Jaycar Electronics

BUY ROBOT ARM & INTERFACE KIT FOR $99 SAVE OVER $20

$149

Makeblock

PROGRAMMABLE ROBOT

Codey Rocky Robot Kit

YOUR NEW CODING COMPANION! KR-9230

Children can learn about programming while they play. Comes in two parts: Codey (detachable mainboard) equipped with more than 10 electronics modules that can be controlled via code, and Rocky (car) that lets you take Codey anywhere you want. Supports AI and IoT. Cloud storage. Ages 6+.

$69.95

BUILDING ROBOT

Robot Arm Kit KJ-8916

Capable of 5 separate movements and can easily perform complex tasks. Excellent project for anyone interested in robotic construction. 100g lift capacity. Ages 12+.

Batteries not included.

USB INTERFACE KIT KJ-8917 **$49.95**

BASIC ROBOT

$49.95

Tobbie the Robot

HEXAPOD KIT KJ-9031

Walk and spin in any direction, beep and flash his eyes while moving around. Ages 8+.

STEM 4 KIDS!

SCIENCE, TECHNOLOGY, ENGINEERING & MATH

$39.95

12-in-1 Solar Hydraulic Robot Kit

KJ-9030

Learn about solar power and hydraulics. 12 easy to build models including crocodile, T-Rex, elephant, monkey, ostrich, scorpion, and excavator. Ages 8+.

$24.95

80 EXPERIMENTS KIT KJ-8970

Demonstrate various theories of electronics - from controlling a motor to a police car siren. Easy snap together parts. Requires 2 x AA batteries. Ages 6+.

$129

Da Vinci 3D Pen TL-4252

DESIGNED FOR CHILDREN. MOBILE & LIGHTWEIGHT.

Draw in 3D, or repair and join existing PLA 3D prints. Non-toxic filament, prints with low heat and leaves no mess. Ages 6+.

FILAMENT TO SUIT TL-4254 **$44.95** NEW

$14.95

KIDS CLOCK KIT KJ-8996

Bright coloured parts. Easy to assemble. No batteries required. 31 pieces. 195mm Dia. Ages 6+.

$24.95

MARS SOLAR ROVER KIT KJ-9026

Learn about science and solar. Easy snap together construction. Ages 8+.

$49.95

CIRCUIT STICKERS STEM PACK KJ-9330

Merge art and electronics! Includes copper tape, batteries, LEDs and heaps of templates and exercises, including circuits, switches. Even the box can be turned into a project! Ages 13+.

STEM

While STEM is a new term, educational products have always been close to what we know and love at Jaycar Electronics for many years. You might recognise products such as the Short Circuits kits, that have been teaching young and old for over twenty years. We have a fantastic range of STEM related products for kids as young as 6. From learning the basic fundamentals of electronics and how to solder to building a robot or an Arduino micro with C++. Learn more at jaycar.com.au/stem

TEACH THEM ABOUT ARDUINO!

Programming Made Easy with Ardublock:
ArduBlock is a graphical drag-and-drop type programming environment for Arduino®. Ideal for kids! By dragging and dropping colour coded blocks into the workspace, a fully functioning Arduino® program can be created easily!

LEARN MORE AT: jaycar.com.au/ardublock

This Linker module and accessories range is based around a series of Arduino® compatible modules, shields and cables that make prototyping easy. It is ideal for schools, big or small kids keen to learn and play with Arduino®. Simply attach linker shields to mainboards and connect with Linker Shields. No soldering required.

$4.95

LINKER JUMPER LEADS
Connects Linker kit sensors/modules and Linker kit base shield. 2.54mm headers for easy and tidy connection. 4 pins, 2.54mm spaced. Sold individually.
200MM XC-4550
500MM XC-4555
1000MM XC-4560

$4.95

LINKER MOMENTARY PUSH BUTTON SWITCH XC-4557
Standard 12mm square momentary button mounted for the Linker connection. Big button and solid tactile click. Can be used as an input or as a reset button
• 28(W) × 25(H) × 10(D)mm

$4.95

LINKER DOUBLE BUTTON MODULE XC-4573
Two momentary push buttons mounted on a single board for Arduino®/pcDuino via the Linker connection. Can be used as a pair of reset and switch buttons
• 21(W) × 25(H) × 11(D)mm

$5.95

LINKER LED MODULES
Designed for beginners of Arduino®/pcDuino to monitor controls from digital ports. Available in four colours and comes in 3mm or 10mm sizes

$10.95

LINKER TOUCH SENSOR XC-4561
A capacitive touch sensor to replace a push button. Low in power consumption, fast response and easy to operate
• 28(W) × 24(H) × 8(D)mm

$11.95

LINKER 4-DIGIT 7-SEGMENT MODULE XC-4563
Uses a chipset of TM1637 to drive a 12-pin 4-digit common anode 7-segment LED. The MCU only needs two GPIO lines to control it
• I2C interface
• 46(W) × 24(H) × 14(D)mm

$15.95

LINKER SLIDE POTENTIOMETER MODULE XC-4575
The slide potentiometer is a linear variable resistor with a total resistance of 10k
• 24(W) × 60(L) × 20(D)mm

$24.95

LINKER BASE SHIELD XC-4557
Allows a connection between all Linker sensors/modules and Arduino®/pcDuino
• Connections: 1 × SPI, 2 × IIC, 1 × UART
• 68(W) × 59(H) × 18(D)mm

All-In-One Learning Kit
XC-3900
This starter kit includes the UNO main board, breadboard, servo motor, light sensor, RGB LED, joystick, buzzer, LED matrix, line tracer, andassorted components and cables.
All supplied in a handy carry case with dividers, and a quick start guide with links to online tutorials.

$79.95

Raspberry Pi 3B+
SINGLE BOARD COMPUTER XC-9001
The latest version of the Raspberry Pi. Tiny credit card size computer
• 1.4GHz 64-bit quad-core processor
• Dual Band 2.4GHz & 5GHz Wireless LAN
• Bluetooth® 4.2 technology with BLE
• Faster processing and networking
• Supports Power-over-Ethernet (with separate PoE HAT)

$84.95

$9.95

RS-232 TO TTL UART CONVERTER MODULE XC-3724
Allows you to connect a legacy device (or computer) to your existing Arduino® board. Full RS-232 port.

$9.95

MICRO SD CARD SHIELD FOR WI-FI MINI XC-3852
Add gigabytes of storage to your Wi-Fi Mini Main Board with this tiny shield and a microSD card. Works with Arduino® inbuilt SD library.

$9.95

DHT 11 SHIELD FOR WI-FI MINI XC-3856
Create a tiny environmental sensor node . Uses pin D4 for DHT11 interface. Suitable to plug into breadboard for prototyping.

$19.95

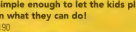
USB INTERFACE FOR JOYSTICK AND BUTTONS XC-9046
Suitable for arcade games, flight simulators or anything that works with a USB joystick.

Neuron Kit:

Great for the little ones, we've provided you with 3 projects with different levels of difficulty and all utilising only a single Makeblock Inventor Kit.

Using the makeblock app, one can learn about different modules and sensors and how to fit them together in a project. But don't worry, these projects are designed to be simple enough to let the kids play and learn what they can do!

KJ-9190



MULTIPLE FACES

ADVANCED

Getting into flow-based programming, use the neuron app to program different faces to show up on the dot matrix display. Perfect to learn about the basics of programming.

A GREAT KIT FOR ALL SKILL LEVELS

TAIL WAGGING CAT

INTERMEDIATE

Make a robotic cat! Requires some adult supervision to cut and glue the cat box. Understand how an engineering project comes together from different systems and structures and get a taste of robotics.

$199

MUSICAL FRUIT

BEGINNER

Make music from actual fruit! Create a keyboard using fruit or other household objects for a tonne of musical fun. Your kids will be excited to learn about electronics and how it can interact with everyday life.

Makeblock LEARN. BUILD. PROGRAM.

Airblock Programmable Drone Kit KR-9220

7-piece modular drone, hovercraft, car, spider and more! Made of magnetic, modular parts that are easy to assemble and disassemble without the need for tools. Controlled by your Smartphone or Tablet. Rechargeable, lightweight & indoor friendly. Ages 8+.

$199
KR-9220

Mbot Bluetooth® Robot Kit KR-9200

Avoid obstacles, follow lines, play soccer, and more. Control from your Smartphone or Tablet, or program using simple drag-and-drop programming blocks or Arduino® IDE. Ages 12+.

$199
KR-9200

TEACH YOUR KIDS ELECTRONICS WITH littleBits™

Piggy money box not included.

WAS $199
$149
SAVE $50

WAS $389
$299
SAVE $90

CREATE TOUCH ACTIVATED INVENTIONS TO CONTROL YOUR STUFF KJ-9120

This Rule Your Room Kit transforms any boring old object into an awesome, interactive invention. 8 inventions. Ages 8+.

CREATE & CONTROL YOUR OWN APP-ENABLED GAMES, PRANKS & CONTRAPTIONS KJ-9100

Build a remote-controlled car or a caterpillar that crawls with the tap of a table with this Gizmos and Gadgets Kit. 16 inventions. Ages 8+.

Edison robotics for everyone

Meet Edison:

ROBOT KIT

KR-9210 **WAS $99.95**

A compact, pre-assembled robot that is built to last. Pre-programmed with 6 robot activities set by barcodes, can be programmed using simple drag-and-drop programming blocks or a Python-like written language. Modular and easily expandable using LEGO® bricks. Ages 5+.

NOW
$84.95
SAVE $15

Edcreate:

EDISON ROBOT CREATOR KIT

KR-9212 **WAS $44.95**

Designed to work with the Edison robot above. 5 projects to build: EdTank, EdDigger, EdRoboClaw, EdCrane & EdPrinter.

Edison Robot Kit sold separately.

NOW
$39.95
SAVE $5

LET THEIR IMAGINATION SHINE!

NEW 2018

STANDARD KIT KJ-9350

$59.95

NEW 2018

DELUXE KIT KJ-9352

$129

Bring your ideas to life with fun, hands-on playful learning with Squishy Circuits. It uses conductive and insulating play dough to teach the basics of electrical circuits, a perfect blend of play and learning! Kits include dough, LEDs, buzzers and more.

STANDARD KIT KJ-9350
Includes everything you need to get started with some more advanced Squishy Circuits projects that use LEDs, buzzers, and insulating dough!

DELUXE KIT KJ-9352
Comes with more items and plenty of pre-made doughs so you can start circuit building right away! Also includes a deluxe battery holder which has a knob that allows your lights to blink and buzzers to beep at different speeds.

CHECK OUT OUR ONLINE VIDEOS

LEARN BASIC ELECTRONICS WITH CIRCUIT SCRIBE

Kids can draw the circuits with the conductive pen and watch them come to life. Each kit includes detailed sketchbook with examples and templates to work through.

NOW **$129**
SAVE $20

ULTIMATE KIT KJ-9300 **WAS $149**
32 piece kit for more complex, robust circuits, which you can hook up to programmable platforms like Arduino® *(Arduino® not included)*.

NOW **$99**
SAVE $20

MAKER KIT KJ-9310 **WAS $119**
17 piece kit to take your circuit sketches to the next level with inputs, outputs, and signal processing in your circuits.

BASIC KIT KJ-9340 **WAS $69.95**
Contains a Circuit Scribe pen, six modules, battery, workbook and accessories to get started. Explore basic circuit concepts like conductivity and work up to creating a touch-sensitive circuit using the NPN transistor. 11pc.

ALSO AVAILABLE: SPARE PEN KJ-9320 **$34.95**

$59.95
SAVE $10

NOW **$39.95**
SAVE 10%

SHORT CIRCUITS BOOK - VOL.1 AND PROJECT KIT KJ-8502 **WAS $44.95**
A great way to teach kids about electronics – no soldering required! Kit includes baseboard, springs and components to make 20+ projects, and 96-page coloured Short Circuits Vol. 1, which is complete with comprehensive assembly instructions and a full technical discussion explaining exactly how the circuit works.

ALSO AVAILABLE:
SHORT CIRCUITS BOOK VOL 1 BJ-8502 **WAS $9.95 NOW $7.95 SAVE 20%**

NOW **$9.95**
SAVE 20%

SHORT CIRCUITS BOOK - VOLUME 2 BJ-8504 **WAS $12.95**
Once kids have learnt the basic skills and knowledge from Short Circuits 1, they can move onto learning how to solder with circuit board-based projects. With this book and kits sold separately, they can make such things as; a mini strobe light, police siren, mini organ, etc. All projects are safe and battery powered. 21 project kits sold separately.
See website or in-store

NOW **$11.95**
SAVE 20%

SHORT CIRCUITS BOOK - VOLUME 3 BJ-8505 **WAS $14.95**
Volume 3 describes how to build over 30 circuit board-based projects (sold separately) such as Ding Dong door bell, simple intruder alarm and amplifier. Soldering techniques are discussed in detail and proper use of digital multimeter. 30 project kits sold separately.
See website or in-store

LEARN MORE AT: jaycar.com.au/short-circuits

We are proud to introduce our new range of 3D printers, scanner & pen (featured on front page) representing fantastic VALUE FOR MONEY with AMAZING FEATURES & RELIABILITY.

JOIN THE 3D REVOLUTION

CHECK IT OUT AT: jaycar.com.au/3dprinting

EASY TO USE. SAFE. AFFORDABLE.

FINDER TL-4220

$499

Fully assembled capable of printing right out of the box with few tweaks. Features are slide-in build plate, assisted leveling, filament run-out detection and more. Single non-toxic PLA filament option keeps your creations simple and fun. Perfect starter 3D printer for families, schools as well as novice users.

- 3.5" touchscreen panel
- Wi-Fi and USB connect
- Low noise operation
- Prints up to 140W(L) × 140W(W) × 140H(mm)

CAPTURE & REPLICATE

HANDHELD 3D SCANNER TL-4250

$399

Scan your desired objects and produce a 3D files. Great for capturing real-world objects and storing them digitally. Compact and lightweight design allows you to move it around the desired target for scanning with ease.

- Connects via USB
- Scan up to 1000(D) × 1000(D) × 2000H(mm)

BONUS $100 FILAMENT
With every purchase of TL-4230 Inventor or TL-4240 Guider II

$1599

SIMPLE. SMART. ACCESSIBLE.

INVENTOR TL-4230

Totally-enclosed design safe to use indoors and around children. It features a stunning 50microns print resolution for a high-quality finish to your prints. Equipped with five cooling fans with temperature activated sensor that regulates the build chamber temperatures. Built-in camera so you can monitor the progress of your prints remotely. Simply download and connect to the mobile app.

- 3.5" touchscreen panel
- Wi-Fi, USB cable & SD card connect
- Resume printing from power failure
- Support dual-colour and sub-material printing
- Prints up to 230(L) × 150(W) × 150(H)mm

Be the first to know when available in all stores but we can easily arrange for you. Please call your nearest store for availability.

$2499

PROFESSIONAL. FULL FUNCTION. EXTRA LARGE.

GUIDER II TL-4240

Constructed from rigid all-metal frame design and body side panels made of high-strength ABS material. Stable print performance and durable. Features are assisted leveling, filament runout detection, file preview and more. Perfect for the architecture and construction sector, science research, manufacturing industries and education.

- 5" touchscreen panel
- Wi-Fi, USB & Ethernet connect
- Resume printing from power failure
- Supports multiple mainstream filament types for diverse printing needs
- Prints up to 280(L) × 250(W) × 300(H)mm

Be the first to know when available in all stores but we can easily arrange for you. Please call your nearest store for availability.

BONUS $50 FILAMENT
With every purchase of TL-4250 Adventurer

$899

NEW GENERATION. SMART. LIGHT.

ADVENTURER 3 TL-4250

- New generation 3D printer with cloud print management. Control printers via the cloud using FlashCloud. PolarCloud. Small but compact structure with no angular design. Ready to use and no levelling printing. Removable, heatable and pendable plate. Built-in camera function.
- 4.3" touchscreen panel
- Wi-Fi, USB & Ethernet connect
- Low noise operation
- Automatic filament feeding
- Prints up to 150(L) × 150(W) × 150H(mm)

MY FIRST WORKBENCH!

1. **10W 240VAC SOLDERING STATION** TS-1610
   - Compact and lightweight
   - 100-450°C temperature range
   - Rotary temperature control dial
   - Integrated soldering pencil holder
2. **30 DRAWER CABINET** HB-6323 **WAS $29.95**
   - 6 rows of 5 drawers
   - Can be mounted on the wall
   - 50(W) × 30(H) × 115(D)mm each draw
3. **PCB HOLDER WITH MAGNIFIER** TH-1987
   - 2X magnifying lens, soldering iron holder, 2 × strong adjustable alligator clips
   - Heavy cast iron base for added stability
   - Requires 3 × AAA batteries
4. **LOW COST DIGITAL MULTIMETER** QM-1500
   - Perfect first meter! Includes transistor & diode test.
   - 500V, 2000 count
   - AC voltages up to 750V
   - DC voltages up to 1000V
5. **ANTI STATIC MAT** TH-1776 **WAS $39.95**
   - Ideal for field service people
   - Mat folds out to work area of 600 x 600mm (approx)
   - 2 pouches at one end
   - Ground lead and wrist strap included
6. **6 PIECE INSULATED ELECTRONIC SCREWDRIVER SET** TD-2026 **WAS $19.95**
   - Excellent temperature stability and anti-static characteristics
   - Fully insulated. 1000V rated.
   - Storage case included

WAS $179 **$149** SAVE $30

0-30VDC 0-5A Regulated Power Supply

MP-3840

Power your devices with precise voltage level and current limits. Easy-to-use LED display panel.

- Avoid overheating, burnout and over-current
- 1mV ripple voltage
- 120(W) x 185(H) x 270(L)mm

WAS $69.95 **$59.95** SAVE $10

5 Port USB Charging Station WC-7766

Charge up to 5 USB devices at the same & boasts a maximum power output of 2.4A per port. Includes 5 dividers and a 12VDC, 4A power supply.

- 165(L) x 120(W) x 62(H)mm

$39.95

25W SOLDERING IRON STARTER KIT TS-1652

A complete set including multimeter, soldering/desoldering tool, screwdrivers, pliers & side cutters.

$16.95

METAL DESOLDER TOOL TH-1862

Made of lightweight metal and has strong suction. Automatically cleans itself with each action.

- 195mm long

$14.95

SOLDERING TOOL KIT TH-1851

A selection of hand-tools and accessories for soldering work. Phillips screwdriver, tweezers, heatsink and 3 double-ended tools for poking, scraping, leg-bending and flux-removal.

$29.95

CUTTERS & PLIERS SET TH-1812

Set of five 115mm cutters and pliers for electronics, hobbies, beading or other crafts. Soft ergonomic grips.

NOW $19.95 ea SAVE $5

INSULATED PLIERS & CUTTERS

Strong, tough and reliable. Can cut piano wire up to 1.6mm. Comfortable double inset handles. GS approved.

7" 180MM BULL NOSE PLIERS TH-1984 **WAS $24.95**
6" 160MM SIDE CUTTERS TH-1985 **WAS $24.95**
6.5" 170MM LONG NOSE PLIERS TH-1986 **WAS $24.95**

$24.95 ea

LEAD-FREE SOLDER

99.3% Tin / 0.7% copper - lead free. 1.00 & 0.71mm (dia.) available. Rosin cored. 200g rolls.

0.71MM NS-3088
1.00MM NS-3094

$29.95

LARGE RARE EARTH MAGNETS LM-1652

Made from NdFeB (Neodymium Iron Boron), providing the highest available magnetic energy of any material. Sold as a pair.

- Nickel coating

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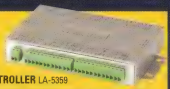

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SERVICEMAN'S LOG

The aircon that nearly made me lose my cool

Dave Thompson*

Like other appliances, air-conditioners won't last forever. But spending a bit more can sometimes leave you with a longer lasting and better made device. However, all good things must come to an end, as our 15 year old aircon started to take flight.

I think I've mentioned I'm involved in a renovation project; I've been working on it whenever I can for the last five months so it does tend to come up in conversation. For example:

Friend: "How's the renovation project going?"

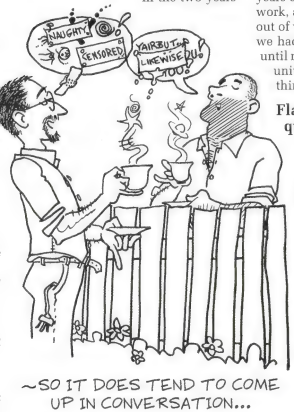
Me: "$#@$%#!!!"

Sprucing up a house from the ground up is not easy at the best of times, let alone in the middle of a harsh Christchurch winter. On the bright side, the project is excellent training for a multitude of DIY disciplines.

In the two years since we moved out, the tenant had run it down – a lot. One expects natural wear and tear but dug up lawns, cut-down trees, damaged paintwork and greasy surfaces are beyond the pale.

It was while I was cleaning some of their old junk from the side of the house that one of the two outside compressor units for the house's air-conditioning system burst into life, making such a terrible squealing noise that I just about had a coronary.

We'd installed these units some 14 years earlier so they'd done plenty of work, and while they were now well out of warranty (by about four years), we hadn't had a problem with them until now. The noise this compressor unit was making now was something else though.



~SO IT DOES TEND TO COME UP IN CONVERSATION...

Flashback: before the quakes

When I called my acquaintance in the air-conditioning industry all those years ago for a quote, he recommended a Daikin system as they had a good reputation and an excellent (10-year) warranty. Admittedly, they were more expensive than other brands, but we've always gone by the philosophy that spending more at the beginning often saves money in the long run.

In other words, don't be penny wise but pound foolish! This strategy has usually paid off, well, most of the time anyway. But that's another story!

Items Covered This Month

- Air-conditioner repair
- One smoking radar
- Yamaha RX V450 receiver repair
- Car fob repair

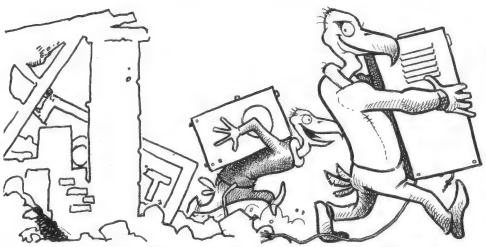
*Dave Thompson runs PC Anytime in Christchurch, NZ.
Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

When I said earlier that we had installed the air-conditioning units, it was actually our professional acquaintance that I have mentioned who did the installation. Having had a look at our place, he decided that the outside units should go at what he called the back of the house, which is actually the side, where a narrow strip of wasted land and a fence separates us from the neighbour's property.

That sounded fine to me and we signed off on the quote he sent us. However, a few weeks later, on the day of installation, I arrived home from work to discover the installers had put the compressor units literally on the back of the house, facing our grassed backyard and the patio/BBQ area.

They'd made an impressive and very clean job of routing the gas and power lines through walls, over the roof and under the house to the various components, but the blasts of frigid air being chucked out over the patio meant it would be winter there all year round! I was also surprised by the sheer size of the compressor units which now took up a large portion of our patio. This simply wouldn't do!

My wife almost had a coronary when she saw them, but by that time I'd called my mate and asked him why the compressors had been placed there, thinking that perhaps the installers had hit some snags that meant they couldn't be installed on the side of the house, where they could blow cold air onto the paling fence and drain water into the unused grass strip.



~THE VULTURES THAT WERE PICKING OVER THE BROKEN BONES OF CHRISTCHURCH BUSINESSES...

He let out a stream of expletives (some of which I'd heard before, while others must have been aircon industry specific) and said he'd be around to check it out. Sure enough, he soon rolled up with the two navvies who actually did the job and made profuse apologies for his employees' lack of apparent intelligence, for mistakenly putting them on the actual back of the house.

I was going to point out that he had written "back of the house" on the quote but given the circumstances (and his extensive vocabulary), thought better of it.

He promised to make things right and a few days later the guys were back, with a couple of others to assist and had soon relocated the compressors to their current location, with power and gas lines re-routed and any old holes nicely filled in and even painted. And there they have lived and worked happily for nearly fifteen years, until the day I was moving rubbish and the fan started up and just about caused an underwear change.

Back to the present problem

The noise was like a jet taking off, winding up to a very shrill level. I immediately flicked the outside isolation switch off and the fan ground its way to a stop. How the tenants had put up with this awful noise, given that one of their bedroom windows was almost directly above this thing, was astonishing. Even more concerning, how did the neighbours put up with the noise without complaint?

Admittedly, there was a driveway separating the neighbour's house from the paling fence but as the crow flies, it was only about four meters to their living room. With the air-conditioning running in our house, the noise must have been truly annoying in theirs!

No prizes for all you diagnosticians correctly guessing the cause of the noise; any serviceman (or enthusiast) worth his or her salt will be shouting: fan-motor bearings! Well, that's what I thought, so my first job was to call my new air-conditioning specialist Clary, who had installed heat pumps in our new place.

My knowledgeable assistant

I'd met Clary through a builder friend and when I discovered that he could install heat pumps for us at our new home, I was sold. We already had the heat pumps as we'd stripped them from our quake-damaged workshop rather than leave them for the vultures that were picking over the broken bones of Christchurch businesses at the time and selling their swag in pub car-parks around the country.

As an example, a multi-thousand dollar customised café POS system was stolen from the wreckage of a building by gang members doing demolition working, while the owner watched, kept away by police and army security who held him behind the cordons for his own safety. This POS system turned up installed in a backwater pub somewhere up north.

Nobody was ever prosecuted for this blatant looting and there were many, many other instances of this happening. We'd paid a fortune to have the heat pumps installed before the quakes, so why leave them? Insurance wouldn't cover the costs, as most insurance companies were being hammered senseless by quake claims (some obviously fraudulent), to the point some required government bailouts.

Of course, aircon systems are supposed to be professionally removed, with the gas recovered properly to avoid pollution, but the fact that the gas lines had been ripped out of the compressor units and were left dangling in mid-air meant there was no gas to recover. So I had no qualms about removing everything myself.

I didn't know whether they could be used again but I wasn't about to let someone nick them and profit from my loss. I was therefore very pleased when Clary looked at my pile of components and told me that he could reinstall them, and for a fraction of the cost of either getting new/refurbished units or the cost of hiring an aircon company to come and do it.

And so it was Clary I called when I heard the noise this older unit was making. Given the current state of affairs where appliances seem to be considered "consumables", designed for replacement rather than repair, I was fully prepared for the fact the motor might not be available. But in that case, I'd either try to replace the bearings, or ask Clary about re-purposing a different motor for this unit.

Surely, given the similarity between different aircon models, it wouldn't be too hard to locate a similar motor that would fit.

While neither of these solutions would be ideal, shelling out for a second-hand compressor unit wouldn't be much chop either, so I sent him a PXT (Multimedia Messaging Service) of the label on the side of the compressor and hoped for the best. Within a few hours, he'd called to say he could get a new motor assembly for a trifling

Servicing Stories Wanted

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$120 plus tax and shipping, which sounded like a pretty good deal.

In the meantime, even though it was below zero most mornings I went to work on the house, I avoided using the heat pump, not because it might get damaged further but because I was embarrassed about the noise, and I didn't really want any trouble with the neighbours.

It took a few weeks for the motor to arrive and Clary messaged me when it did, asking if I wanted him to install it, or do it myself. I asked him the likely cost of him doing it and he reminded me that I'd looked at a circuit board for him about a year previously, and because I hadn't charged him for repairing it, he would change the motor over for me for nothing.

What a surprise, as I'd forgotten about doing that little job for him, and just goes to show what a little karmic investment can reap. I pledged to help him though, partly out of a sense of duty and partly out of professional interest, because I'd never seen the internal workings of one of these units before.

Getting to the motor

He arrived early one clear-but-bitterly-cold morning and we set about swapping out the motor. He first fired the thing up and we chatted as we waited for the compressor to kick in and the fan to start. When it did, we weren't disappointed and Clary immediately agreed with my diagnosis that the fan motor bearings were almost certainly the cause of the noise.

Getting things apart on the compressor unit looked quite straightforward, with just a few sheet-metal screws holding the exterior panels on. I thought this job would be a cinch; talk about your famous last words!

Clary started on one screw with a large Phillips head screwdriver and immediately it became clear that the screws were a little tight. I grabbed another, smaller screwdriver and started with other screws, while he braced himself and cranked harder on his stubborn fastener.

You can imagine the grunting and swearing, and Clary was the same, especially when his screw head sheared off, leaving the screw's threads fused to both the panels and the rivnut-type threaded insert.

While most of the screws had combined Phillips/7mm hexagonal heads, suitable for a socket or crescent wrench (shifter for you Australians), as the screw had failed using just a screwdriver, I expected it would shear even more easily using a socket wrench.

I had no luck at with any of the other screws with my smaller driver either, so we resorted to a liberal application of penetrating oil spray on all visible, to-be-removed screws. While the oil did its work, we did manage to remove the plastic front shroud, which used beefier, coarser-threaded screws.

After the four shroud screws are removed, the panel slides upwards and this releases several plastic clips holding it to the front of the compressor unit. Without knowing this trick, I would likely have resorted to levers and prying to release it, so almost straight away Clary's knowledge and experience made things easier.

Removal of the shroud cover exposed the fan, a large-diameter, three-bladed plastic unit. I was surprised at how small the now-visible motor was, given the size of the blades.

Once again, Clary's experience showed as he mentioned that the fan nut, a nylock-type, might use a left-hand thread. As it happened, it didn't, and we discovered that because the nut was quite loose.

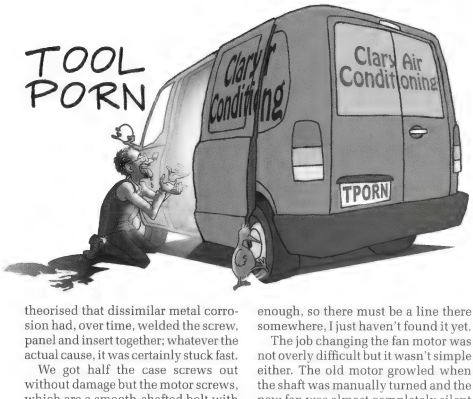
Clary had a socket for this task, assuming it would also be tight, but he found when he applied the socket that he could actually spin the nut off by hand.

He'd mentioned that sometimes the fans can be a real pain to remove from the motor shaft, but in this case, the nut spun off the usual way and the fan came off just as easily, revealing the motor and mounts behind.

By this time, we hoped the penetrating oil had done its job, as it was obvious we'd have to remove the top, front and one side panel in order to unplug the old motor's lead from the controller board. This sat inverted near the top of the case in a water-tight plastic box. Having removed that, we would need to route the new motor's cable and plug it back in.

They certainly could have designed this a bit better, given that the cable on the motor needed to be about one metre long in order to snake around the plastic PCB case to reach the buried socket on the opposite side!

The next screw we tried to remove also failed but this time it took the threaded parts with it, leaving a larger hole than before. On viewing it, I



theorised that dissimilar metal corrosion had, over time, welded the screw, panel and insert together; whatever the actual cause, it was certainly stuck fast.

We got half the case screws out without damage but the motor screws, which are a smooth-shafted bolt with a small threaded piece on one end, all sheared off in the pressed, sheet-metal mount. What fun this job was becoming!

In the end, we just went for it and whatever screws we had to drill or wind out with pliers we coped with. Fortunately, none of the fasteners were critical, except perhaps the motor mounting bolts which pass through and tighten onto rubber mounts to keep vibrations to a minimum. For those, we just drilled out the jiggered holes and re-threaded them for the slightly larger threads of some new bolts that Clary had in his bits boxes.

It helps to have good tools

Whilst helping him to find new screws, I couldn't help but admire the contents of his work van. Talk about tool porn! He had tools and gas-fitting stuff I never knew existed and his van had just about any tool or device you'd need for installing heat pumps.

While it can be difficult to justify the outlay for some of these tools, given you might only use them once in a blue moon, it's a fact that when you need a specific tool for a specific job, and nothing else will do, then you'd be glad you bought it. Well, that's my theory anyway, and is what I usually try to tell the wife when I want to buy some new widget or tool for my workshop!

That said, it does get to a point where even a workshop isn't big enough, so there must be a line there somewhere, I just haven't found it yet.

The job changing the fan motor was not overly difficult but it wasn't simple either. The old motor growled when the shaft was manually turned and the new fan was almost completely silent when we fired it up, so that was definitely the problem.

Hopefully, the neighbours appreciate their newfound peace and quiet. I doubt they realise how much work went into achieving it!

A smoking radar transformer

R. E., was responsible for repairing large radar systems – not a job for the faint-hearted! Some years ago, he found an unexpected fault while performing the first six-month service on a newly installed radar. Here's his story...

This new radar system had replaced an older unit that had been in service for many years. It was a 250kW unit, one of many similar radars operated by this particular government department. It comprised a transmitter/receiver unit and associated scanner control gear, all located in an equipment room on the ground floor of the building, except for the scanner itself which was mounted on the second-storey roof.

The scanner was connected to the equipment room via a rather long and convoluted waveguide, with bundles of cabling carrying power and control data, both of which I had helped to install.

By this stage, I had the service on this type of radar down to a fine art, which included greasing of the mechanical gear trains in the elevation and azimuth system, removal of the slip ring brushes and cleaning of the slip rings that carry the power to, and data from, the elevation part of the radar scanner.

I also checked all power supply voltages and ran checks on and tuned up the radar transmitter and receiver. This ensured that the transmitter was both on frequency and putting out the correct power and that the receiver was tuned correctly and had the specified sensitivity.

The mechanical service, while messy, was simpler on this radar than on the older unit that it replaced, as the previous radar had two large oil-filled gearboxes for the azimuth drives (one high speed and one low speed) plus an elevation gearbox, all of which had to be drained and refilled every six months. There were various points where I had to inject fresh grease, too.

The service on this new radar initially went well, as you would hope and expect with a new radar. The entire process took two days, with breaks for operational requirements, as at times it had to actually be used for the purpose for which it was installed, during which I busied myself with work on other equipment at the station.

I was finished with the radar itself around lunchtime on Friday, which was good since I had a 400km return trip to get home for the weekend. Just one check remained – I had to test the station's backup generator, which had only been installed just prior to my visit. It had been tested off-load by the contractors who had installed it but they had left by the time I was ready to load test it.

So, having warned the station staff, I went out to the station meter box and switched off the three-phase supply to the site. After a short delay, the generator started and I checked that the oil pressure and other readings were OK, then wandered back into the office to make sure all the equipment was still working properly.

When I stepped back in, the first thing I noticed was a burning smell, which did not initially alarm me as the station staff often produced odd smells when they were cooking. But as I walked into the radar equipment room, I was horrified to see smoke pouring out of the radar control rack and hurriedly switched off all power to the radar.

I could hear a crackling sound coming from the back of the radar interface

and as the smoke slowly cleared, I saw a toroidal transformer that had clearly cooked up.

This was odd as it surely couldn't be a coincidence that this happened right when the generator fired up, but the only thing that had changed was the power source. A quick check showed that every other piece of equipment that was in the office, and on-site, was operating perfectly well.

I checked the power coming from the generator but each phase was close to 240V, as expected, and I couldn't find any other issues using the equipment I had on hand.

Anyway, clearly, I would have to replace the transformer which was now the extra-crispy type. To start with, I would have to remove the radar interface, which connected the control computer to the rest of the radar, to get a closer look at the burnt transformer. I was relieved to find that we had a spare transformer available so I at least had a chance of fixing the radar that afternoon.

I started by drawing a diagram showing which connectors went where at the rear of the interface. I had learnt the hard way not to rely on my memory of what goes where, as many of the cables were not labelled.

Since it was a new design and only recently put into operation, I knew nothing at all about this system and was more than a little hesitant about working on it. But I really didn't have a choice at this stage.

Access to the components was by undoing numerous screws on the top panel and flipping the large lid over to reveal the components all mounted underneath that top panel on solder tag strips, none of which were labelled, and all connected via hook up wire, most of which was the one colour – pink.

All I could do was use my multimeter to figure out which connection went where. Then when I was finished, I would need put it all back together, laboriously re-connecting all the plugs, wait for the radar's five-minute warm up-timer to finish, then apply high voltage and see if it was working. If not, I would have to start the whole tedious process again.

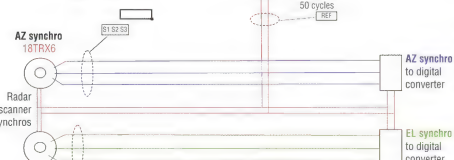
At least the interface on this new radar was less complicated and easier to access than the old one. So, I dug into it, removing all connectors, undoing the interface rack mounting screws and dragging it out on top of a trolley, where I could work on it. During this process, I labelled the connectors and sockets so I would have a reasonable chance of putting it back together properly.

I could now see the damaged transformer and the fact that it had gotten quite hot was obvious, with melted plastic insulation and other signs of heat stress.

My circuit diagram showed that the purpose of this transformer was to supply 95VAC to the radar synchro receivers. These are small devices somewhat like motors except that they are used to determine the rotational position of the radar.

I checked the resistance across the transformer load and got a reading about half that which I measured from a spare synchro; I had expected this as the transformer drove two synchros. This suggested that it was not a short circuit at the output which had caused the transformer to burn out.

I swapped in the spare transformer and added a temporary unofficial modification: an inline fuse holder and fuse in the secondary of the transformer, on the cable powering the synchros, just in case I was wrong about the transformer load being the problem.



A diagram showing how the toroidal transformer drove the "synchros" in the radar.

After refitting the upper board, remounting the interface in the rack, and then reconnecting the myriad of cables to the rear of the unit, I was ready to power it up.

At this stage, the generator was still providing the mains power. I decided to risk powering the radar back up while still on generator power since it was the only way that I could think of to prove whether the generator was the root of the problem.

I crossed my fingers and flicked the breakers. The radar initially seemed fine but after about 30 seconds, I could once again hear the crackling sound of overheating insulation and a quick glance at the interface showed that the replacement transformer was starting to cook. And the fuse had not blown.

This was not totally unexpected and suggested that the fault was not in the radar itself, but something to do with the generator. I had no option but to once again power down the radar and ponder what to do.

Clearly, the radar could not be operated like this. Even if I had a second spare transformer, I could hardly fit it and leave since if the mains dropped out and the generator came on, that would be the end of the radar again and could possibly result in a fire. In fact, it was lucky that this was the first time the generator had been used.

Well, if these toroidal transformers would not work on the generator power, perhaps a different type would. Certainly, the rest of the transformers in the radar, and other equipment on site, was handling it without a problem.

I realised that the 95VAC required for the synchros was similar to the 110VAC used for American mains. There was a very good chance that the local Dick Smith (remember them?) might have a step-down transformer meant for powering American equipment in Australia and that could be suitable for this job.

By this stage, it was getting close to 4.30pm, so I jumped in the car and tore down to the store before they closed and was rewarded with a small step-down transformer complete with mains lead and plug. Its 100V output was not exactly as specified but I figured the worst that could happen was that the synchros might run a little warmer.

I wired this in place of the toroidal transformer. The result was not pretty but I was pleased to see that turning

the radar on again resulted in full operation and no burning smell. I hung around for an hour or so monitoring the operation to ensure that nothing untoward happened with this new transformer in circuit, then took off for the day.

Of course, this was not a permanent solution, but it did get the gear back on the air, which was most important, and would allow me to return home the following day, once I had checked the operation again in the morning to confirm that all was still going well.

Back in the workshop the following Monday, I ordered both a replacement toroidal transformer for the unit and a spare for the spares cupboard. I then contacted the contractor responsible for the supply of the generator to let them know that something was amiss and that the generator installation was not acceptable.

I also contacted a transformer manufacturer to chat with them and they told me that a "shorted turn" that can occur with toroidal transformers, depending on how they are mounted. This sounded very much like the problem that I had seen, though how it occurred was something of a mystery to me.

I should mention that toroidal transformers were pretty new technology back then and I didn't yet understand them all that well. Almost all the previous equipment that I had worked on used the older-style E-I core transformers.

The contractor replied sometime later that week that they had found that the office earthing had not been done correctly at the generator but that it had now been rectified.

My theory is that the Neutral from the station was tied directly to the Earth at the generator, which somehow caused a shorted turn effect via the metal mounting bolt and plate that was holding the transformer to the earthed metal base plate. But truth be told, I really do not know for sure and now that the radar was completely operational again, I had other things to think about.

Once the replacement toroidal transformers turned up, at the next possible opportunity I returned to the station and fitted the specified transformer and a test run with the generator showed that the radar would now run off the generator with no problem, which was a significant relief to me.

Mentioning this problem to the main workshop further south seemed to provoke some disbelief until later the following year they encountered the same problem at an identical new radar installation, whereupon they contacted me to let me know that the same thing had happened to them!

Yamaha RX V450 5.1ch receiver repair

J. W., of Hillarys, WA, decided to help a friend out by repairing a cherished Yamaha surround sound receiver. He was rewarded for his generosity in liquid form...

A friend asked me to look at his Yamaha RX V450 5.1-channel receiver. It was quite a few years old and had recently become difficult to switch on. Sometimes it would power up but other times would take a number of presses of the power button. Now it would not power on at all.

I removed the cover and found that the incoming mains supply went to a small PCB. This seemed like a good place to start. I removed the PCB and examined it through my magnifying lamp but couldn't see anything unusual.

At this point I decided to try to find a circuit diagram on the net, I located the one shown here. The small PCB was called the sub power board and was responsible for providing power to the main PCB to run the infrared receiver and the coil of a relay which is used to switch power to the main transformer.

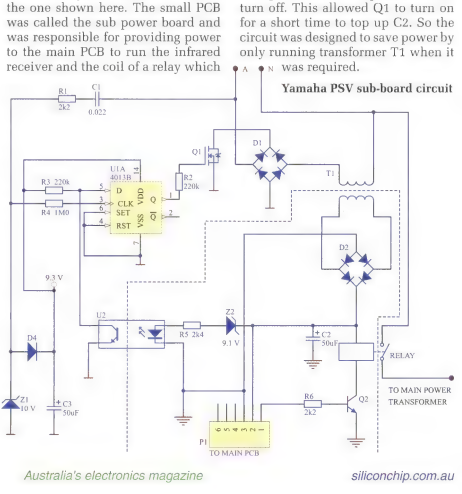
The circuit operation was difficult to understand at first. Current from the mains Active flows through a 22nF capacitor and 2.2kΩ resistor to a 10V zener diode and this arrangement then feeds a 9.3V rail via diode D4 to power a 4013B flip-flop which drives the gate of Mosfet Q1.

Q1 switches current through a small transformer, T1, via bridge rectifier D1 and this transformer provides a 12V standby rail for the main PCB.

I hooked up the sub power PCB to the mains via an isolation transformer. The voltage across Z1 was only 6.4V, not 10V as I expected. The circuit seemed to work to some degree as there was 8V across C2.

I decided to remove C1 and measure its value as the coupling capacitor in this type of circuit has proven to be a problem before. C1 measured only 10nF, not 22nF as it should be. I replaced it with a mains-rated (X2 class) 22nF capacitor and powered up the board again. I then observed 10V across Z1 and 12V across C2.

The voltage across C2 slowly dropped under load until it fell low enough to make the optoisolator Q2 turn off. This allowed Q1 to turn on for a short time to top up C2. So the circuit was designed to save power by only running transformer T1 when it was required.



I reassembled the receiver and ran it for a few days. The difficulty switching on had disappeared so I gave it back to my friend, who now has his surround sound system working again. He generously came around with a bottle of scotch for my efforts.

Editor's note: failed X2-class capacitors have become a theme in our Serviceman contributions. We think it must be due to their "self-healing" properties, where damaged sections of the metal plating will burn away so that the capacitor does not short the mains.

But this results in their value dropping and eventually, it will drop far enough to cause the device to malfunction.

What causes the damage in the first place? It may be that the capacitors are poorly manufactured and simply degrade over time but it seems more likely that it's due to voltage spikes in the mains, from thunderstorms and such.

This type of circuit for reducing the receiver's standby power was used for many years in Yamaha products. They were one of the earliest manufacturers to reduce standby power of their appliances.

The resulting standby power figures are impressive, at around 100mW. This is made possible by switching mains across the transformer periodically, minimising the average magnetising current.

Car remote repair

R. W., of Lakes Entrance, Vic, found that even a simple repair job can be satisfying and can save quite a bit of money too – especially when the item that's being repaired is in the automotive realm. Replacement electronic parts for cars can be surprisingly expensive so fixing them is often worthwhile...

Cars and oil are usually a good combination but this time, it lead to an unusual service challenge. My daughter now owns my father's old Nissan Pulsar and it was one of the early models that adopted remote locking, boot release and a panic button (which sets off the alarm). It has been a very reliable runabout.

But after spending a week or two in Melbourne and borrowing the car on numerous occasions, I became aware the remote locking fob was not reliable and while the lock button would always work, unlock often did not.

...THESE THINGS ARE NOTORIOUSLY EXPENSIVE TO REPLACE

These things are notoriously expensive to replace so a repair was definitely worth a try.

Using a coin, I cracked the fob open and found a large button cell in good condition. I bought a new cell and replaced it but no luck; it made no improvement.

Having to think a bit harder, I inspected the fob and prised the PCB out of silicone insert which held it in place and also formed the rubbery buttons that poked out the other side.

To my surprise, the whole thing was covered with a greenish goo. At first it looked like corrosion, but the the silicone cup was actually full of oil. It looked like clean engine oil and it was everywhere. My daughter assured me she knew nothing about it so I am guessing the key fob's oil soaking had happened before she started driving the car.

While there was no evidence of corrosion affecting the operation of the remote, the oil had been there long enough to stiffen and gum up the switches. Strangely, there was no oil at all on the battery side of the fob. Perhaps the silicone part had formed a gasket, stopping it from getting into the back of the remote.

I washed the oil off the PCB and silicone by applying turpentine and scrubbing it with an old toothbrush. The brushing must have been overly vigorous though, as one of the metal-bodied SMD tactile switches was left with only one leg out of four still attached. Using my finest soldering tip, I re-soldered the three detached pins on one switch and refreshed the solder on all the other switches.

Then, using a fine hair brush, I dabbed fresh turpentine on each switch in turn and using a metal probe, quickly pressed the switches off and on many times. This action released goo from inside the switches that I then wiped away. Cycling around the switches in turn, washing and clicking gradually flushed all the goo out, giving a satisfying click when each was pressed.

I repeated this over and over until I was happy the turpentine was clear. I then used methylated spirits to give the PCB a final clean, to remove any turpentine residue.

My daughter and I were both pleased to find the clean new fob worked properly again. While literally a small job, it was a most satisfying challenge and my father would have surely been pleased too. He was of the conviction that nothing could be thrown out unless it had been repaired at least two times already! SC

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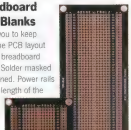

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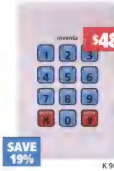

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Retro-fit any push-button garage door for remote control!

WIRELESS REMOTE CONTROLLER

Do you have a motorised garage door (or two!) which you open by pressing a wired-in pushbutton switch? Wouldn't it be nice to be able to press a remote control button in your car as you drive towards it? (It's great for cold, rainy nights . . .) This project will do just that for you.

Many homes have electrically-operated garage doors, gates, etc, usually powered by 230VAC mains. But invariably the pushbutton switch to raise/lower or open/close them is controlled by a much safer low voltage – usually 5V or 12VDC.

That's why you'll find the vast majority of controller pushbutton switches connected to the controller via bell wire, mini figure-8 or even a couple of strands of rainbow cable, none of which would be anything like mains rated.

So you should be able to tinker with the pushbutton side of the controller to your heart's content, knowing you're not going to get yourself across any nasty voltages!

The pushbutton switch is almost always a single pole, normally-open type; more often than not it is a simple "doorbell"-type switch. When pushed briefly it will raise the closed door, lower or close the open door, or stop the door from opening or closing further if the switch is pushed mid-way through its travel. (The latter is quite important if accidents – such as squashed children, pets, toys etc – are to be avoided!).

Design by Branko Justic
Words by Ross Tester

One other important word in the last paragraph is "briefly": invariably, the garage door controller is looking for a very brief switch closure – anywhere from a few milliseconds up to, perhaps half a second.

One thing it does NOT want is a permanent-until-pressed-again action a such as you would get from a latching-type switch. In normal electronics parlance, it wants a "momentary" action.

Adding remote control

Because the up/down/stop switch is simply a pushbutton, other switches can be and often are, wired in parallel. For example, as well as a switch inside the garage, there may well be a switch in the house itself so that you don't have to go into the garage to close the door.

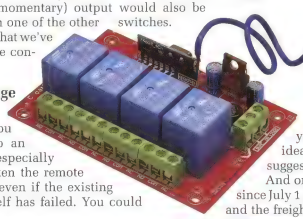
Or there may even be one hidden outside if there is no internal house-to-garage access. Or there may be a switch at the doorway into the garage so you don't have to squeeze past any vehicles to get to the normal switch (often installed at or near the door[s]).

One person we know has just this setup but he's also wired in a hidden magnetic reed switch. His wallet has a tiny magnet in it which normally keeps the magnetic flap closed – but if he's outside and wants to open the garage door, he simply waves his wallet close to the reed switch and . . . presto! (Anyone hoping to find out how he achieved the wallet magic wouldn't have a clue!).

All of these switches are simply wired in parallel and, as we said earlier, the connecting wires are usually pretty light gauge. They carry very little current.

So it stands to reason that if you want to add wireless remote control, its (momentary) output would also be wired in parallel with one of the other switches.

And that's exactly what we've done with this remote controller.



What if your garage already has one?

Doesn't matter! You can add this one to an existing controller, especially if you've lost or broken the remote (see above right!) or even if the existing remote controller itself has failed. You could save a fortune!

As it simply goes in parallel with the existing push button, you could also use it as a much cheaper way to give another family member remote access. The existing controller won't be affected.

In fact, I know someone who put one of these in his garage even though the existing one worked fine – he said it was a LOT cheaper than buying extra "brand name" handheld remote control units for his family members!

The controller

While we have presented a number of UHF remote controllers over the years, we're going down this route because ready-made UHF transmitters and receivers have now reached an almost give-away price.

For example, the assembled TX10 transmitter PCB from Oatley Electronics sells for just $8.00 in a four-button keyfob, as seen below! The matching high-security receiver will set you back just $5.00.

Or you can buy the complete K180XPX kit – **two** transmitters, receiver plus the decoder/relay driver PCB and all the bits you need (four relays, LEDs, power supply components, etc) along with a suitable plugpack supply for just $40.00 plus p&p.

Two key fob transmitters are shown here, one with its protective cover closed (to prevent accidental presses) and the other open, ready for action. Another module-based transmitter is also available but these are the ones we prefer.

We have to be honest – you can buy ready-made UHF remote controllers, transmitters and receivers, online for much the same price (and sometimes lower) than the kit we're using.

Lost your remote control?

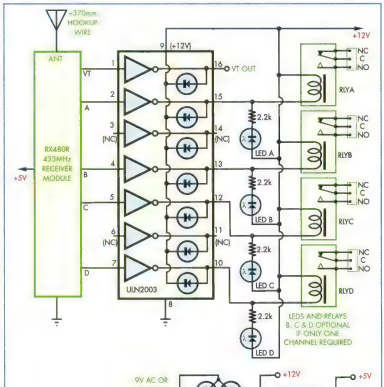
Talk about coincidence (or is it Karma?). Just the other day a colleague (g'day Dave!) rang me bemoaning the fact that his trusted tenants had "done a runner" leaving him in a bad way.

Lasing the rent owing was bad enough, then he went on to say that they'd also absconded with the only garage door remote controller. "It's a really old system and they don't make those controllers any more. I've been quoted more than five hundred dollars to replace it," he moaned.

"Have I got some good news for you," I said. "I can solve your problem for less than fifty bucks . . . "

But that means you won't have the thrill (or practice) of building something yourself. And you won't have much of an idea how or why it works. Which is why we're suggesting using this kit of parts.

And one point that many online buyers now miss: since July 1 you now have to add GST to the online prices and the freight, which might make that "attractive" price



SC 10/2018 **UHF REMOTE CONTROLLER**

Fig.1: the controller PCB also contains the pre-assembled UHF receiver/decoder along with the 9VAC/12V DC power supply, powered by an external plugpack. You have the choice of building for one, two, three or four channels.

a little less competitive!

There are three parts to the K180X kit:

(a) The transmitter, which is supplied pre-built and mounted in a key fob with four push-buttons. Depending on which button is pressed, it sends a coded signal in the 433MHz band.

(b) The 433MHz receiver module itself, which is also supplied pre-built, ready to mount on

(c) The controller PCB, which simply accepts the decoded signal from the receiver, turning on the appropriate relay (one of four).

We should mention that an alternative transmitter, the TX10 module, is also available but we believe the keyring-mounted transmitter will be much more popular. However, some readers may have other applications for the remote control system so we mention it in passing only (see the Oatley Electronics website [www.oatleyelectronics.com] for more details).

Switching mains voltages

A word about the controller: while the relays are labelled as "10A, 250V" we don't believe you should be trying to switch mains voltages with this project.

As we said earlier, the switching side of (we believe) ALL garage door controllers is done at low voltage so there is no need to provide the extra insulation and care needed for a mains-switching project.

If you want to adapt this project for another use which does involve switching mains, our advice is to be extremely careful – it is something you should only do if you have experience in building projects involving high voltage.

In other words, it's not something for a beginner to undertake, whereas the project as it stands is ideally suited for those with little construction experience.

To be frank, we would prefer to keep this solely as a low-voltage switching device; if you want to switch mains we would be much happier to see it used in conjunction with a mains relay board (ie, the relay switching another relay).

We have published two projects specifically designed for this (It's certainly not a new problem!).

The first was back in May 2006 – a Remote Mains Relay (siliconchip.com.au/Article/2665). It used either a switch or closing contacts to control a beefy (10A, 250V) relay on a PCB with widely-spaced tracks. Unfortunately, though, it was prepared in conjunction with Dick Smith Electronics so for obvious reasons is no longer available.

If there is demand, we may revisit this in the future.

The second, the Remote Mains Relay MkII of January 2009 (siliconchip.com.au/Article/1272), was slightly more complicated but it offered more features, including a relay rated at 20A, 250V and all but the mains input and output sockets mounted on one large PCB.

This PCB, code 10101091, was the same as used the USB Sensing Power Switch in January 2009 siliconchip.com.au/Article/1441) and is still available from the SILICON CHIP Online Shop. All components used in this project are common, garden-variety devices and should be available from your usual supplier.

Incidentally, you may be wondering why most relays have a much higher AC switching rating than their DC rating. For example. the "Songle" brand relays used in this project have a rating of 10A at 250VAC or 28V DC.

The reason is simple: when the contacts open and they interrupt a high current, they will usually draw an arc which could weld the contacts closed – not exactly what you want.

For 50Hz AC, the voltage drops to zero every ten milliseconds so there is nothing to keep the arc going. But with DC, the voltage stays constant so the arc may continue.

The problem is worse the higher the voltage so the rating for DC is reduced to about 10% of the AC voltage.

How it works

Let's put the cart before the horse and look at the receiver/relay board first of all. It is shown in Fig.1.

It has a bog-standard power supply on board which can handle either an input supply of 9VAC or 12V DC. It does this by putting the input supply through a small bridge rectifier (BR1), smoothed by a 100µF electrolytic capacitor. This provides the ~12V DC required to power the relays. (9VAC x 1.4142 = ~12.7V DC, less the losses across the diodes in the bridge rectifier.)

And because of the bridge rectifier in circuit, the supply voltage (if DC) can be connected with either polarity.

Following the bridge is a 7805 positive regulator, the output of which is smoothed by another 100µF capacitor. This gives the 5V supply which powers the rest of the circuit.

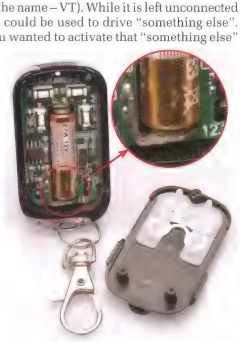
The 5V DC is also brought out to one of the terminals on the 3-way power socket – it can be used for other peripherals requiring a regulated 5V DC supply. The other two terminals accept the AC or DC input.

A tiny 433MHz receiver module wired to the PCB receives a coded signal – from up to perhaps 10m or so away – from the matching transmitter. The (prebuilt) transmitter module has four push buttons so you can have up to four "channels" being controlled.

The RX480R-4ch receiver module similarly has four outputs which drive up to four small relays via a ULN2003 relay driver. This actually has seven inputs and outputs; we are only using five.

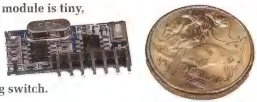
Hang on – didn't we just say this is a four channel system?

That's true, only four of the ULN2003 outputs are connected to relays. But a fifth output, called the "VT" output can be used to verify that a valid transmitter signal has been received (hence the name – VT). While it is left unconnected in this circuit, it could be used to drive "something else". For example, you wanted to activate that "something else"



Inside the TX10 key fob transmitter, shown here mainly to reveal what happens when a battery's insides like to explore the outside world! The four white buttons are actuated by the flexible membranes on the key fob top.

The receiver module is tiny, as this photo shows. The white push-button at top right is the programming switch.



if *any* key on the remote control transmitter was pressed.

Note that this is equivalent to a "NC" output – ie, it is normally high and goes low when a button is pressed and a valid signal is received. When the button is released, it goes high again.

Naturally, the other four outputs independently switch their on-board relay if, and only if, the appropriate push button on the remote control transmitter is pressed.

Well, even that is not absolutely true because one of the three modes of operation is to "latch and reset" – the button pressed activates the appropriate relay but at the same time resets the other three relays if they are currently activated.

Bearing in mind our earlier comments about not being recommended for mains switching, each of the four relays has a normally-open (NO), normally-closed (NC) and common terminal. To use it like you would use a switch, you would connect between the NO and common terminals.

Along with the relays, the ULN2003 also powers four LEDs (one per relay) to give a visual indication of the relay being pulled in. There is no such indication on the VT output, though this would be easy enough to arrange if you wanted one (eg, via a LED and 2.2kΩ resistor in series connected to +12V).

Incidentally, if you only need one channel you only need to solder in one relay and one set of terminals; two for two and so on.

Momentary or latching relays

Invariably, commercial garage door controllers are activated by a brief press of a "momentary" pushbutton switch (perhaps for half a second or so). You definitely do not want the switch to stay on once you remove your finger, if only for the simple reason that you would not then be able to open or close the door (it would stay open or closed while ever the switch was "on").

Perhaps even more importantly, there are some garage door controllers which warn that holding the pushbutton on for a long period risks the control circuit being damaged. That's a remote (pardon the pun!) possibility but a possibility nevertheless.

So we set up the remote controller to mimic the momentary switch. This is done when you program the receiver module.

We mentioned earlier the "latch and reset" mode. In case you haven't worked it out by now, the other two modes are simply "momentary" or "latch".

The transmitter

Let's now look at the transmitter module. As we mentioned, there are actually two available – one a module to be constructed but the more convenient is supplied pre-assembled. It's in a small keyfob and has of four user buttons (A, B, C & D) protected by a sliding cover (to prevent inadvertent pressing!).

The A and B buttons are larger; presumably they'd get the most use. A tiny LED pokes through the front of the

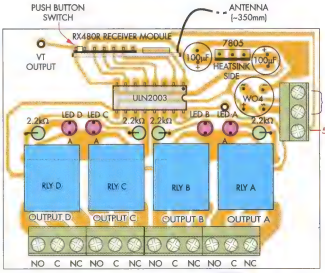
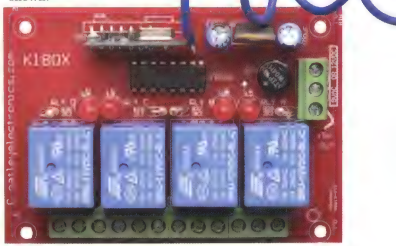


Fig.2: component overlay and matching photo of the receiver/controller PCB. The receiver must go into the board as shown!



module to show when any button is pressed.

We've shown the internals of a TX10 transmitter, if for no other reason than to reveal a trap for young players.

If you look carefully at the negative end of the battery in this photo, you can see that some of its insides are now . . . outside! Fortunately, this one has not gone too far and is salvageable but you might not be so fortunate!

The problem is that, like many devices coming out of China with batteries supplied, their quality is often questionable (it's certainly not the first leaky battery we've seen!) and you have no idea how old the battery is anyway.

To be frank, we'd throw away the battery and replace it with a fresh, known brand (eg, Eveready or Duracell etc). Sure, that might seem like you're wasting a battery, but . . .

Meanwhile, back at the ranch . . .

The K180X is one clever system! Unlike some el-cheapo modules, it uses a rolling code which has around one million possibilities. And it changes its code every time it is used so that in the unlikely event your code was recorded off-air (and there are plenty of 433MHz receivers around which could do it), using the same code again will have no effect.

The code-hopping happens automatically; once you

have set the transmitter to match the receiver (and we'll get to that shortly) you don't have to worry about it again.

Construction

Only the K180X controller PCB needs to be assembled – as we mentioned earlier, the preferred transmitter is supplied pre-built and ready to rock. The tiny 433MHz receiver module is also pre-built and only needs to be soldered in place on the main (controller) PCB.

Follow the PCB component layout, Fig.2, and its matching photo.

Start with the resistors, electrolytic capacitors and LEDs, followed by the regulator IC and the bridge rectifier. Obviously, watch the polarity for the capacitors, LEDs, regulator and bridge. The top side of the PCB is clearly marked. Also solder in the 3-way "power" terminal block – make sure its access holes point outwards towards the edge of the PCB.

The ULN2003 is the last "component" as such to go in – again, it must be inserted with the notch on the IC matching the notch on the PCB.

All that's left are the relays and the terminal blocks. Their terminal pins will only allow them to be inserted one way. As we mentioned earlier, if you only need one channel, simply install relay A and its associated components.

It's more than likely that your existing garage door controller will also switch on a light for a preset period – and this will still happen so you don't have to get involved with mains wiring.

The terminal blocks come in sets of three – to fit on the PCB, you will need to slide the tongue and grooves on their sides together. Again, the access holes point outwards.

An antenna

There is no provision on the receiver PCB for an antenna track so you'll need to add one, preferably before soldering in the receiver module (it can be done later but it's a bit easier now!).

The antenna connection point is clearly marked on the back of the PCB, diagonally opposite the other connections.

433MHz has a wavelength around 700mm; a quarter-wave antenna (~173mm) made from a length of fine hookup wire would be fine. This could be left straight, dangling from the PCB, or if you're putting the controller/receiver in a case, could be curled around into a coil (exact size is not important).

It's only if you're after absolute maximum range that the length of the antenna becomes more critical.

Just make sure you don't have any bared end of the antenna wire to short onto anything else.

The receiver

The tiny RX480R receiver module solders in vertically with the component side toward the edge of the controller PCB (it is possible to put it in back to front but it certainly won't work and more than likely will be damaged.

So check twice before soldering!). Our photo and component overlay (Fig.2) shows the orientation clearly.

A case?

We assume the receiver/controller will be mounted inside the garage, if not close to the garage door controller switch then close to a power outlet. But even though it might be out of the elements, we'd be inclined to mount it inside a small case to protect it from moisture, dust, critters etc. Unfortunately it's just too big to fit into Oatley's HB1 Jiffy Box but it fits easily into their HB2 Jiffy Box (130 x 67 x 42mm).

That box is only $3.50 and we consider it a sensible investment (order at the same time as you order your K180X kit to save on postage).

There are four holes drilled in the corners of the PCB (on a 76mm x 63mm rectangle) which make for easy mounting. You'll also need to provide small access holes for the power leads, the wiring to the door controller switch and, if you wish, an external antenna. Each of these are on different sides of the PCB so they won't get mixed up!

Once the unit is built and tested, we'd put a dollop of silicone sealant over the holes, again to stop little pests making their home inside.

Programming

It's not so much programming as selection of operating modes (as discussed earlier – momentary, toggle and toggle with reset).

Once the receiver learns the mode, it stays set that way until changed. The same is true for the codes – the receiver knows what code to expect.

Apply power to the receiver. Absolutely nothing should happen!

While the receiver should be devoid of any memory, you can ensure it is cleared by pressing the tiny reset pushbutton switch (directly opposite the antenna terminal) eight times. The LED will flash eight times to confirm this. Then the receiver can be programmed to operate as follows:

For **momentary** mode, press the button ONCE and the LED will light. Now press any button on the transmitter. Each of the receiver relays will operate when their corresponding transmitter button is pressed and release when the button is released

For **latching mode**, press the button TWICE. Again, the LED will light. Press any button on the transmitter and each of the relays will then operate when their corresponding transmitter button is pressed but not release until the same transmitter button is pressed again.

For **latching with reset mode**, press the button THREE TIMES. As before, the LED will light and the relay associated with that push button will pull on, while all other relays will release. The same applies to any other relay and its pushbutton.

SC

Where from; how much:

There are several options available. You can purchase *only* the receiver ($5.00 each) or *only* the controller PCB with receiver and components ($26.00 each) or *only* the prebuilt key fob tran-smitter ($8.00 each) if you wish.

We'd have to ask why you'd want the separate components (except, perhaps, to get extra key fob transmitters).

By far the best option is to purchase the full K180XPX kit, which not only gets you all of the above, you get a second key fob transmitter *and* a suitable mains plugpack, all for the princely sum of $40.00 plus P&P.

As we mentioned in the text, we'd also add an HB2 Jiffy Box at the same time ($3.50) and save a bit on p&p.

More information is available on Oatley Electronics website (oatleyelectronics.com).

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SFX Super Sound Effects Module

Part 2: construction & set-up

You will be amazed by what this tiny powerhouse can do. Whatever sound effect you need, of whatever length, for whatever purpose . . . this little beauty will do it. And it's even got an audio amplifier on board! Now it's time to put it together and get it to do some real work . . .

By Tim Blythman & Nicholas Vinen

This new Super Sound Effects Module is tiny and not particularly complex. But it is very flexible and capable, thanks to its smart software.

We described the circuit and some of the software features last month. Even since then, we've made some refinements – see panel opposite.

Now let's get into assembling the module. We'll also describe how to test it, configure the software and put it to use.

Board design

We've made the Super Sound Effects Module very compact so that it can fit just about anywhere. We've also given it flexible supply options. And while it is tiny, we've avoided using any parts which make assembly too difficult.

The most difficult compromise we've had to make is with the micro. We needed one with more than 20 pins to provide all the required functions, as well as enough computing power for all the input/output tasks while mixing digital audio data in real time.

Since we also wanted a very low standby power consumption, that left us with very few options.

That meant the only suitable package for microcontroller IC1 was the 28-pin Small Shrink Outline SMD package (SSOP). But don't let the closely spaced pins put you off because, with the right tools, it is not difficult to solder. Most of the other components have much larger pins

so once you've fitted IC1 to the board, you should find the rest of the construction process quite straightforward.

We highly recommend that you have a magnifying lamp on hand, some precision tweezers and a temperature-controlled soldering iron (ideally with at least one fine and one medium tip). You will also want some good quality flux paste and desoldering braid in addition to your usual tools.

As shown in the parts list published last month, most of the passive components are in 2012 (metric) or 0805 (imperial) packages which have a 2.0 x 1.2mm footprint. These are slightly smaller than components in 3216/1206 packages, which are also quite common.

We find they are not really any more difficult to solder, while saving quite a bit of space on the board. So they are the obvious choice for this project.

Because many of the components (especially the capacitors) don't have any visible markings, it pays to work with one value at a time.

Construction

While today's PCBs are of a very high standard, it is always a good idea to check for shorted or broken tracks before fitting any components. Check carefully around where IC1 will sit, as this is where the finest pitch pins are located. Having said that, the chances of finding a problem on the boards we supply is very low.

As we go through the assembly, we'll mention component orientations with respect to the board having the microSD card socket on the left, as shown in the main overlay diagram, Fig.3. As most of the components are small, we

suggest that you set the temperature of your soldering iron a little lower than you would for soldering larger, through-hole components.

Fig.3 shows the position of all the components on the top of the board but note that you would fit only one of LK1 or LK2, not both. There are a few components on the bottom side and their locations are shown in Fig.4 but you should fit these last, otherwise, the board will not sit flat on your bench.

If you are planning to use a 5.5-18V DC supply, you can leave off some components, as shown in Fig.5. For a 3V DC supply only, fit the components shown in Fig.6.

Note though that if you need to be able to change the supply arrangement later, it will be easier to fit all the components now, except for one of LK1/LK2 (as shown in Fig.3). The kit of parts that we supply comes with all these parts; the only real advantage of leaving some off is that you save a bit of time.

Fine-pitch ICs first

Start by soldering IC1 first since it has the closest pin spacings. It comes in an SSOP-28 package, which has pin 1 marked by a small circular dot on the top surface. With the microSD card slot to the left, pin 1 goes to the bottom right and this is indicated by a white dot on the PCB.

Apply some flux to the pads on the PCB and place IC1 in position as closely as possible. Hold it in place by gently pushing down on it and carefully tack one of the corner pins in place.

Some constructors like to use a wooden (spring) clothes peg to hold the IC in position while soldering – as well as giving you back a hand, it precludes that awful smell of burning fingers!

Some revisions since last month

Inevitably, we've made some tweaks to the software since writing the article last month, in order to simplify it. That's what happens with software; it is always capable of being refined.

The first change is to the pin used for varying the playback speed (pitch). Rather than using separate pins depending on whether you are using an analog voltage or pulse rate to control playback speed, we found a way to combine both of those functions into pin 10 of IC1, which is connected to pin 5 of CON4 (the SW4 input). So now there is a single configuration setting for the playback speed control function.

This was achieved by using the audio output interrupt service routine (ISR) to count pulses, rather than using the hardware pulse counter (TIMER3). Since this ISR runs 46875 times per second to feed the DAC, by checking the pin 5 state in this routine, pulse rates up to 23kHz can be measured, assuming a 50% duty cycle (or 4.7kHz with a 10% duty cycle).

We've also made it possible for this pin to control playback volume as well as speed. Any input can have its speed or volume (or both) controlled by the signal at the SW4 input.

For example, with a model train, you could use read the locomotive's motor voltage (via a suitable divider) as a proxy for speed and use that to control the engine sound. At low motor voltages, the volume and pitch will be low and will steadily increase from a low rumble to a loud roar, giving the impression of having higher RPM and working harder as the motor speeds up.

Alternatively, a potentiometer or variable resistor can be connected to this pin and used as a simple hardware volume control.

The SW4 input can also be set up so that an increasing analog voltage can be mapped to a decreasing volume or speed. This is set for each input individually, so effects like cross-fades, where one sound increases in volume as another decreases, are possible.

The section in the main text on configuration explains all these settings and how the input signal controls the output sound.

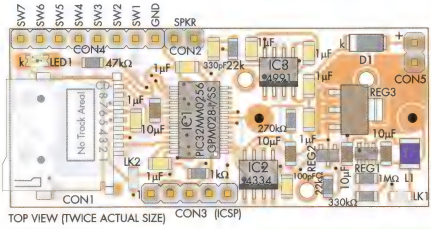
At this stage, it doesn't matter too much if you bridge some of the pins together, as it's possible to remove the bridges with solder braid later.

If IC1 is sitting flat and all the pins line up correctly with their pads, tack down the pins on the other corners to lock it in place. If it is not correct, apply the iron to the first solder joint and nudge IC into the correct location. It may take a few tries before it's perfectly aligned. Try to avoid spreading the solder too much to adjacent pins during this process.

Once you are happy with the location, solder all the pins to their pads. If you have applied flux, then all you should need to do is load some solder onto the tip of the iron and touch it to the ends of the pins where they contact the board. This will draw a small amount of solder from the iron, using the minimum necessary to make the joint. Keep the tip of the iron clean, and add a small amount of solder directly to the iron each time it runs low.

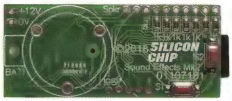
Now use a magnifying lamp to check thoroughly for any bridges. These can be removed by applying some flux to the top of the affected pins and then pressing some clean solder braid to the pins with the iron. Repeat until all the pins are soldered and not bridged.

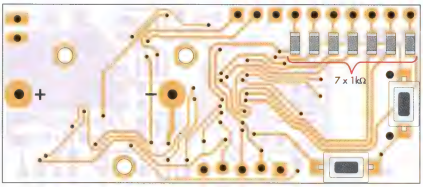
We also found it helpful to use a



TOP VIEW (TWICE ACTUAL SIZE)

Fig.3 (left): component overlay diagram for the top side of the board, shown at twice actual size for clarity, with a matching 1:1 scale photo above (CON2, 3 & 4 not yet fitted). Do not fit both LK1 and LK2 ; LK1 is for a 3V DC supply while LK2 (as shown above) is fitted for the 5.5-18V DC supply option.





UNDERSIDE VIEW (TWICE ACTUAL SIZE)

Fig.4 (right): similarly, the underside overlay, also shown twice actual size, with 1:1 photo above. Seven 1kΩ resistors are located on this side of the board, along with optional tactile switches S1 and S2, which can be used to trigger the first two sound channels.

smartphone (a digital camera will do a similar job) to take a close-up photograph. If you do this, you may not have to strain your eyes as much, especially if you look at the photos on a large screen.

When you are happy with the soldering job you've done for IC1, move on to the microSD card socket and REG1. Their pins are not as closely spaced as those of IC1 but other nearby components will make it more difficult to solder them later.

The microSD card socket should be a bit easier to align than IC1 as it has plastic pins which go into holes on the PCB to help locate it.

Apply some flux to each pad before dropping it into position. Holding it in place, tack down one of the larger tabs on the shell to ensure it stays there.

Once it is flat and you are sure that it is correctly aligned and located, solder all the larger tabs to hold it in place. Now, in a similar fashion to IC1, apply a small amount of solder to the iron, then carefully touch the iron to each pin to solder them to the PCB.

You can use the same technique as for IC1 to remove any accidental bridges. Be careful not to bridge any pins to the shell, as this is connected to ground.

If you are using REG1 then it is fitted next. It also has a dot to indicate pin 1 but since it is so small, it is difficult to see. You will probably need to use a magnifying lamp to see it.

Place REG1 in its spot towards the bottom right of the PCB with pin 1 to the top right, near the REG1 marking on the PCB, with the small dot under the R.

As before, tack one pin in place, confirm the other pins are correct, then solder them all and remove any bridges as necessary.

Remaining components

Now we can mount the passives, which are larger and easier to solder. A pair of fine tweezers will be handy here and a small amount of flux on the pads can even help in this case, too. There are seven resistors and one 0Ω link to mount on the top side of the board.

Refer to the relevant overlay diagram to see which resistors go where. Table.1 shows the codes likely to be printed on the top of each value of each resistor. The 0Ω resistor is for LK1 or LK2, depending on your power supply; fit LK1 if you installed REG1 earlier, otherwise fit LK2.

While it's a bit tricky, it is possible to solder a 2-pin header onto each set of pads for LK1/LK2 so that you can use a jumper shunt to select between the two supply options. But that would only be necessary if you are not sure which one to use in your application.

There are up to thirteen capacitors on the PCB. Be careful not to get these mixed up after you remove them from their packaging as they will not be marked with any values. The only way to identify them if you get them mixed up is with a capacitance meter. Fit these in a similar manner as you did for the resistors, again using the overlay diagram and PCB silkscreen as a guide as to which goes where.

If you fitted REG1 earlier then solder inductor L1 in place now. Like the resistors and capacitors, it is a 2-lead device but it is a bit larger. You can solder it in much the same manner but it will probably take a little more heat to form good solder joints.

If you did not fit REG1 then you will need to fit diode D1. This is also a 2-pin device but is polarised and must be orientated with the cathode stripe to the left.

LED1 is next and it goes in the top-left corner of the PCB. It too is polarised and normally it will have a green dot or other marking to indicate its cathode. However, we have seen SMD LEDs with a dot to indicate the anode (ie, the opposite end) so you should use the diode test function of a multimeter to check which end is which.

It will light up with the red multimeter probe to the anode, so the black probe will indicate the cathode.

If it doesn't light up either way around, either you are not making good contact with it or your multimeter is not supplying enough voltage to light it up. Once you have identified its cathode, solder it in place with the cathode facing to the left.

The last components to fit on the top side of the board are regulators REG2 and (if fitted) REG3 and chips IC2 and IC3. Solder them in that order, by tack-soldering one pin first and then checking the placement of the other pins before soldering the rest.

REG2 and REG3 can only be fitted one way but you will need to be careful with the orientations for IC2 and IC3. If fitting REG3, smear some flux paste on its pads first and note that you will need to heat its tab for longer than the other pins, to ensure the solder has formed a good joint.

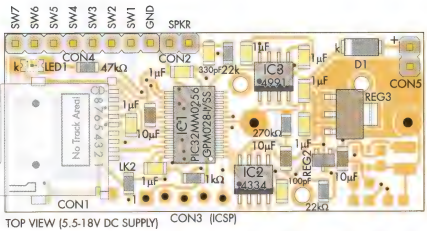
IC2 should have the number 4334 visible on top while IC3 will be marked 4991. There will be a small depression on the top of IC2 adjacent to its pin 1, which should be orientated so that it is closest to the ICSP header (CON3).

IC3 is soldered near the top of the board with its pin 1 to towards microcontroller IC1, ie, facing the same way as IC2.Now flip the board over and solder the seven 1kΩ resistors onto the pads as marked.

The two tactile pushbuttons, S1 and S2, can now be fitted if you want to use them.

Additional components

If you want to solder headers for CON2 (the speaker output), CON3



TOP VIEW (5.5-18V DC SUPPLY)

Fig.5: this diagram shows which parts you can omit if you only want the 5.5-18V DC supply option. In this case, power is applied via pin header CON5 or supply wires soldered directly to its pads.

(in-circuit programming for IC1) and CON4 (trigger inputs) then do so now. These can be vertical or right-angle headers and can be soldered on whichever side of the board you prefer. Or you may simply prefer to solder wires directly to the pads on the board instead.

The staggered pins on the ICSP header (CON3) allow you to "plug in" a header to the board without soldering it. This can be useful if you want to program IC1 but don't want a header sticking out of the board when you've finished.

You will need to attach a speaker or piezo transducer to get sound from the module.

An 8Ω speaker is recommended if you are using the 5.5-18V input, but is too much of a load on its own for the 3V battery input, as its amplifier output power is very close to the maximum output of the boost regulator.

For the 3V battery input, the piezo transducer is the simplest option but an 8Ω speaker in series with a small value resistor (say 100Ω)) will reduce the load on the circuit and as a result, it will likely sound better too.

Programming the microcontroller

If you purchased the micro from the Silicon Chip Online Shop, either by itself or as part of a kit, it will have already been programmed so you can skip to the Testing section below. If we do release an updated version of the firmware later, you could use these instructions to load it into your PIC to take advantage of any improvements.

It's easiest to program the micro once it has already been soldered to the board.

You will need an in-circuit serial programmer (ICSP) like the PICkit 3 or new PICkit 4 (see the review in this issue).

Take a standard 5-pin header and push the short end into the staggered holes for CON3. It should be a relatively tight fit and the header won't immediately fall off the board. You don't need to solder the header as friction will make good enough electrical contact to enable programming. However, try to avoid wiggling the header or applying force as it will eventually become loose and will no longer have good electrical contact.

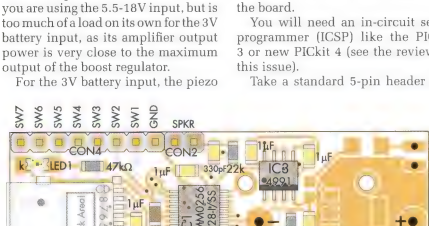
You will need the HEX file which can be downloaded from the Silicon Chip website as part of the software package for this project. You will also need a recent version of Microchip MPLAB X installed on your system. It is a free download; you can get it from www.microchip.com/mplab/mplab-x-ide

It includes an integrated development environment (IDE) and an integrated programming environment (IPE). For this task, it is easiest to use the IPE so when installation is complete, launch that and select your programmer and set the IC type to PIC32MM0256GPM028 (see Screen1). Next, click the Browse button to the right of the Source: field and select the HEX file that you downloaded earlier.

Plug your programmer into CON3 on the board, ensuring that its pin 1 lines up with the pin 1 marker on the board.

You need to apply power to the PIC so that you can program it. You can either do this by connecting the power supply that you intend using to run the board later, or you can set up the PICkit to supply power to the chip.

To do this, switch the IPE software into Advanced Mode via the Settings menu, "log on" using the default password, click the Power button at left,



TOP VIEW (3V BATTERY SUPPLY)

Fig.6: this diagram shows which parts you can omit if you only want the 3V DC battery supply option. In this case, power is applied via wires soldered to the large pads marked "+" and "-" (or pins 2&3 on CON3)..

SMD Resistor codes

Qty	Value	4-digit code	3-digit code
1	1MΩ	1004	105
1	330kΩ	3303	334
1	270kΩ	2703	274
1	47kΩ	4702	473
2	22kΩ	2202	223
8*	1kΩ	1001	102
1	0Ω	0	0

*7 are mounted on the underside of the PCB

SMD resistors are marked with a 3 or 4-digit code to indicate their value; however the numbers are pretty small and you may need a magnifying glass or loupe to read them!

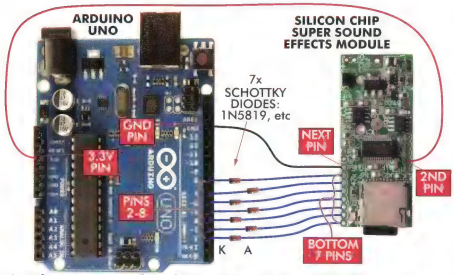


Fig.7: this is one way to drive the Super Sound Effects Module from an Arduino Uno. The red wire provides 3V power from the Uno (the black wire is the ground connection). The seven schottky diodes protect the 3V inputs on the SFX module from the 5V outputs of the Arduino.

enable the "Power Target Circuit From Tool" checkbox (see Screen2). Having done that, click the "Operate" button at left to return to the original screen.

You can now program the chip by pressing the "Program" button. Check the output window below to make sure that programming is successful (see Screen3 below).

If you get an error message, check that there is a good electrical connection between the programmer, header and board and that pin 1 is in the correct position. Check also that the board is receiving power as expected.

Once the chip has been programmed, the board is ready for testing.

Testing

You will need a power supply that can deliver up to 250mA in short bursts. Refer to Figs. 5 & 6 for an overview of where power can be supplied to the PCB.

If you have built the board for the 3V supply option (by fitting REG1) then a battery holder with two AAA cells is a good option. During development, we tested using the 3.3V supply from an Arduino board, two AAA cells and both a PICkit 3 and PICkit 4 to supply power. All four options provided sufficient current for the Super Sound Effects Module to operate adequately.

You may have noticed the footprint for a button cell holder on the back of the PCB. We originally intended this unit to be able to be powered from a lithium button cell but the cells we tested could not provide enough current. Hence, our recommendation that you use AA or AAA cells.

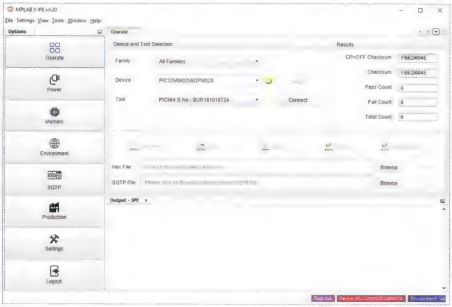
When the unit is powered up without a microSD card present, it starts in a mode which allows you to trigger the built-in samples. So the simplest test is to connect up a speaker or piezo transducer, apply power and then short pins 1 and 8 of CON4, pulling the SW7 input low.

Note that these pins are at opposite ends of the header. You should hear the word "zero" being played back on the speaker.

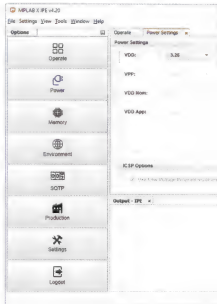
If you do then that suggests it's all working normally and you can proceed to test with a microSD card, as explained below. But if you don't hear that word then you will need to check that the supply voltages on the board are correct and that there are no construction errors such as bad solder joints or swapped or incorrectly orientated components.

Voltage checks

If using the 3V supply option, you have about two minutes between applying power to the unit and REG1 being shut down when IC1 goes into sleep mode. So make sure to do your



Screen1: the MPLAB X IPE programming software is a free download and can be used in conjunction with a PICkit to load the firmware (HEX) file into the PIC microcontroller.



Screen2: this advanced options screen in the IPE software allows you to control whether the

Interfacing with the Super Sound Effects Module

You might be satisfied experimenting with the Super Sound Effects Module on a breadboard with jumper leads but if you are looking to incorporate it into another project, you will need to come up with a way to interface to it.

In some cases, you may want to trigger sound effects using something like an Arduino. Keep in mind though that most Arduinos run from a 5V supply while microcontroller IC1 in the Super Sound Effects Module runs from 3 – 3.3V.

The 1kΩ series resistors on the trigger inputs do allow you to connect them directly without risking damage but there are some techniques that you can use to make the interfacing a bit smoother.

Since the trigger inputs on the Sound Effects Module have on-board pull-ups, you only need to actively pull those pins low. To set those pins to a high state, the driving device can simply set its output pin to a high impedance and they automatically return to a high level.

So in the case of the Arduino, we can switch the corresponding output pin to a logic low output to activate the trigger and then set it to input mode (instead of driving it to logic high) to release the trigger. Using pin D2 as an example, the Arduino code to set the pin as an active low output is:

```
digitalWrite(2, LOW);
pinMode(2, OUTPUT);
```

and the code to set it to a high impedance and allow it to return to a high level is:

```
pinMode(2, INPUT);
```

If for some reason you are using a control device which can not emulate this type of open-collector/open-drain output, the alternative is to connect a schottky diode in series with each input, with the anode toward the input. It will be forward-biased when the output is low, pulling the input down, but reverse biased with the output is high, preventing current from feedback back into the Sound Effects Module (see Fig.7).

You may also want to generate a square wave with a variable frequency to apply to the SW4 input of the Sound Effects Module, to vary the volume or playback rate of certain sounds.

If you are using an Arduino Uno for control, you can easily do this by connecting the SW4 trigger input to digital pin 5 on the Uno.

You can then use this line of code to control the frequency:

```
tone(5,300);
```

In this case, it will generate a 300Hz square wave. It would be a good idea to use the schottky diode in this case since the output pin will be actively driven high half the time.

Interfacing with a DCC decoder

We've said that the module is ideal for model railways and if you are running a DCC system, you are probably interested in connecting the Super Sound Effects Module to a DCC decoder for installation in a locomotive (or even simply connected to the track and hidden in an item of scenery).

If you aren't running DCC, the options are more limited, especially as the track is not powered when the locomotive is stationary.

Since DCC decoders may provide a 12V (or higher) swing from their digital outputs, you should connect schottky diodes in series with each output that goes to the Sound Effects Module, unless you know for sure that those outputs are "open-collector" types.

checks within this time-frame.

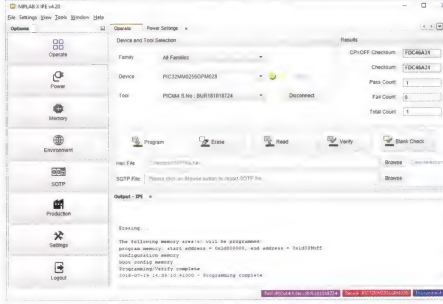
First, check the 5V rail voltage. You can measure this between pins 4 and 8 of IC3 (which are in opposite corners) and you should get a reading in the range of 4.9-5.1V. If you don't then either REG1 or REG3 is not operating properly (whichever is fitted).

If you have fitted REG3 and are not getting a steady 5V reading (and assuming the supply has not timed out as noted above), carefully check the soldering on REG3 but also on L1, the nearby 1MΩ and 330kΩ resistors and the two 10µF capacitors.

A problem with any of these could prevent REG3 from operating.

Assuming the 5V rail is OK, check the 3.3V rail next. This can be measured on the bottom pad of LK2 (closest to the edge of the board), regardless of

PICkit will supply power to the micro being programmed via the checkbox near the bottom.



Screen3: once the PICkit is plugged in, the HEX file loaded and power applied, click Program and if the operation is successful, you will get a similar output to that shown here.

whether LK2 has been fitted.

For a negative reference, the tip of the black multimeter probe can be pressed into the tab of REG3 (or the pad for the tab, if it has not been fitted).

You should get a reading between these two pads in the range of 3.25-3.35V. If it's outside this range then something is amiss.

Since you've verified the 5V rail voltage, it's likely to be a problem with REG2 or a short circuit elsewhere.

Remember to check this soon after applying power if running from a battery, as this rail will also be shut down eventually to save power.

Testing with a microSD card

We supply some example WAV files and a configuration file ("CONFIG.TXT") in the software download package for this project.

Copy those files into the root directory of a microSD card, plug it in and power the unit up.

If LED1 is flashing then you may have a problem with the soldering on the SD card socket or there may be a compatibility problem with the card.

We've tested the unit with a range of cards and it works well with all of them but it's possible that some cards are not supported. So if you can't get it to work, we suggest you try a different brand/model of card just to eliminate that possibility.

If LED1 is not flashing then you can short pins 1 and 2 of CON4 (or press pushbutton S1 if you've fitted it) and you should hear the first sample being played back. That will confirm that the unit is fully operational.

Configuration file format

The configuration file (CONFIG.TXT) is simply a text file consisting of several lines which set the various parameters for the device.

It does not matter what order the settings are listed unless a parameter is repeated, in which case the last instance will override any previous settings given for that particular parameter.

The line starts with the name of the parameter to set, followed by an equals sign (=) and then the value(s). If there is more than one value for a given parameter, they are separated by commas (,).

For example, one line may look like this:

Configuration parameters

MAINMODE

Currently, the software only has one mode which is called "mixed" and this refers to the fact that if multiple sounds are triggered, they will be mixed together before being played back.

We suggest that you include the

"MAINMODE=MIXED"

line in your configuration files to ensure compatibility with future software versions which may add other modes.

MASTERVOLUME

This sets the volume for all channels. Its sole parameter is a whole number between 0 and 256. 256 means maximum volume, however, this can lead to clipping and distortion if multiple loud sounds are played simultaneously.

You may need to experiment with this value. A good value to start with is 128 (ie, half maximum volume).

LOGIC

The LOGIC parameter can be set LOW or HIGH, which dictates whether sounds are triggered when an input is pulled low (the default) or high.

The pins have internal pull-ups in either mode, so sounds can be triggered using external switches, relays, transistor collectors or FET drains to pull these pins to ground.

STANDBY

This sets how long the Sound Effects Module will wait after playing the last sound before it goes into low-power sleep. If set to zero, the module will never go into sleep mode. Use this setting if the power supply cuts out when the module is not in use. The SPEAKBACK function will say "power standby off" in this case.

The value given is in seconds, up to a maximum of 357 (which is just under six minutes). When it goes into sleep mode, current consumption is around 20µA if running from a 3V battery. If a sound is triggered in this mode, playback will take up to half a second to resume (but typically around 250ms). This is because the SD card needs to be re-initialised each time it is powered up.

So the standby timer provides a compromise – there will be a slight delay between the first trigger event in sleep mode and the sound being played back but the unit will then remain in idle mode for the specified time so that subsequent trigger events will not incur any delay.

So if you are running the unit off the battery, you will want to have a non-zero sleep mode to avoid draining it too quickly.

But if running from mains-derived power or if you are cutting the power externally when the unit is not being used (eg, using a physical switch) then you can set the idle period to zero to disable sleep and avoid the delay upon wakeup.

In the case of a non-zero timeout, the speakback will read back as "power standby" followed by the number of seconds. In the low power mode, the amplifier and boost regulator are shut down, which also means that the microSD card will shut down.

SWITCH1 to SWITCH7

The number following "SWITCH" refers to a trigger input. The parameters dictate what sounds are triggered when that input is activated. These are five control values, followed by between one and ten file names.

The first control value is the playback mode for this input which also dictates how many sound files can be referenced. This is either LOOP, SINGLE, CROPLOOP, CROPSINGLE, ASR, ALTLOOP, ROUNDROBIN or RANDOM. The first four modes require just one file, while ASR takes up to three and ALTLOOP takes two. The last two modes, ROUNDROBIN and RANDOM can use between two and ten files.

If more files are listed than necessary for a given mode then they are ignored. If a file name is left blank then no sound is played in that case.

The second and third control values set the volume for files triggered by this input. The first volume is what we call the low volume and the second one is the high volume. They only need to differ if you are using the variable playback volume feature which requires a control signal to be applied to the SW4 trigger input.

The SW4MODE parameter is used to enable this (see below). If enabled and the low and high volumes are different, then the playback volume for sounds triggered on this input will vary between those two values, based on the signal at the SW4 input.

The fourth and fifth control values are used to vary the playback speed/pitch, with the values being the low sampling rate (#4) and the high sampling rate (#5).

These work in a similar fashion to the volume parameters, and also have a nominal value of 256. So with a value of 256, the

switch1=loop,256,dtmf.wav

Note that file names cannot contain an equals sign or a comma as this would cause problems parsing the configuration file. Note also that there cannot be spaces before or after the equals sign or commas.

The configuration file is parsed in a non-case-sensitive manner, ie, it doesn't matter whether names are written using lower case letters, upper case or a mixture.

This is also true of how file names are handled; like Windows, they are matched in a case-insensitive manner. So a file called "Train Horn.wav" can be referred to as "train horn.wav" or "TRAIN HORN.WAV" and it will still work.

Refer to the panel listing the configuration parameters below for an understanding of what each line does.

If you are familiar with programming or shell scripts, you might be accustomed to placing a hash (#), a double slash (//) or single quote (') at the start of a line to "comment it out" so that it is ignored.

Any of these characters can be used in the CONFIG.TXT file to achieve that effect.

Here's an example of a typical configuration file:

```
MASTERVOLUME=128
LOGIC=LOW
STANDBY=120
SWITCH1=ASR,64,256,112,384,DIESEL1.WAV,DIESEL2.WAV,DIESEL3.WAV
SWITCH2=ASR,256,256,256,256,HORN1.WAV,HORN2.WAV,HORN3.WAV
SWITCH3=LOOP,256,256,256,256,BELL.WAV
SWITCH5=SINGLE,256,256,256,256,ANNOUNCE.WAV
SWITCH6=ASR,256,256,256,256,WHISTLE1.WAV,WHISTLE2.WAV,WHISTLE3.WAV
SW4MODE,ANALOG,1000,3000
SPEAKBACK=NONE
```

playback rate will equal the file's sampling rate, while higher values will play it back faster and lower values slower.

The minimum possible playback rate is 1kHz and the maximum is 65kHz. Generally, you would use files with sampling rates around 8-22kHz so this gives plenty of scope for adjustment.

It is possible for the low volume to be higher than the high volume, in which case the volume will decrease with an increasing control signal on the SW4 pin. And the same comment applies for the playback rates.

Any subsequent values after these five parameters are interpreted as file names. Files must be stored in the SD card's root directory. They must be in PCM (uncompressed) WAV format, with either 8-bit or 16-bit samples and in mono or stereo.

SW4MODE

The first value for this parameter is either TRIGGER, FREQUENCY or ANALOG. If the mode is set to TRIGGER then the SW4 input can be used to trigger sounds like any of the other trigger inputs.

If the mode is set to ANALOG then the voltage on that pin instead controls the volume and/or playback rate of audio samples triggered by other inputs.

Two additional parameters must be provided and these are the lowest and highest expected voltages (in a whole number of millivolts) on this pin. These correspond to the minimum and maximum volumes and playback rates specified for the affected trigger inputs.

If the mode is set to FREQUENCY then the pulse rate/frequency applied to this pin is used to control volume and/or playback rate of audio samples triggered by other inputs. Two additional parameters must be provided and these are the lowest and highest expected frequencies (in Hz) on this pin. These correspond to the minimum and maximum volumes and playback rates specified for the affected trigger inputs.

If the voltage/frequency at SW4 is outside of the specified range then the volume or playback rate will be "pegged" at the minimum or maximum value; ie, if the voltage/frequency is below the minimum voltage then you will get the minimum volume or playback speed and if it's above the maximum then you will get the maximum volume or playback speed.

Within the specified range, the effect is a smooth transition between the limits.

Note that if you are using the ANALOG mode, the software enables an approximately 350µA pull-up current on the SW4 pin. If this pin is driven from a low-impedance voltage source then the pull-up current will be overwhelmed by that source.

But this allows you to connect a variable resistor between SW4 and 0V and then control the voltage on this pin by varying the resistance.

For example, a 5kΩ variable resistor will give a voltage of between 0.35V and 2.1V (note that there is already a 1kΩ series protection resistor in the circuit).

But the pull-up current value is nominal and the actual voltage range may vary slightly.

In FREQUENCY mode, the maximum frequency is around 23kHz (assuming a 50% duty cycle) and the resolution is about 5Hz.

Again, the pin's internal pull-up is enabled, allowing a transistor connector or Mosfet drain to pull this pin low to control the frequency.

SPEAKBACK

The SPEAKBACK debugging parameter can be set to ALL, SUMMARY or NONE, and defaults to ALL to make troubleshooting easier.

When set to ALL, the values provided for all the above parameters are "read out" via the audio output when the Super Sound Effects Module starts up.

This is done by playing back audio samples stored in its internal flash memory (these samples take up about 95% of the flash space).

It is not possible to read out the individual file names, so in each case where a file name is encountered, you will either hear "OK" if the file is present or "NOT OK" if it has not been found or is too small to be a WAV file.

Note that at this point, the unit has not actually checked the contents of the file, so you may hear "OK" even if a file is corrupt or is not in the correct format

When SPEAKBACK is set to SUMMARY, the result is the same as above except that it skips over the settings of the SWITCH1-7 parameters to save time. If set to NONE, no reading out occurs and the unit starts normal operation immediately upon power being applied. So you would normally have a line reading "SPEAKBACK=NONE" in your configuration file once you are sure the settings are correct. SC

Arduino NFC Shield

This low-cost NFC (Near-Field Communication) shield for Arduino uses the same technology as RFID and contactless payments (payWave/PayPass). It allows just about any Arduino board to read data from NFC/RFID tags or cards or write data to certain devices. You can also exchange data with other NFC devices, including many smartphones.

This shield, plus an Arduino module, could be used as the basis for a number of useful devices, for example, to unlock a door using an access card, to monitor the passage of stock or other items on a conveyor belt, to transmit business card information to customers' smartphones and so on.

But before we explain how it works, we will explain how RFID and NFC work.

NFC or Near-Field Communication is a set of protocols that enable two electronic devices to exchange data by bringing them within about 40mm of each other.

Communication is by electromagnetic induction, ie, coupling signals between loop antennas in each device. In effect, when the two antennas are brought within 40mm of each other they form an air-cored RF transformer.

NFC involves low-power RF signals with a carrier frequency of 13.56MHz, in one of the globally available and unlicensed ISM (industrial, scientific and medical) bands.

One of the devices involved in NFC communication can be passive, ie, with no onboard power source. This is typically the case with RFID (radio-frequency identification) tags and smart cards.

In this situation, the device that is powered powers the circuitry in the passive device via the energy of the 13.56MHz RF carrier. The passive device then "replies" by modulating the carrier, with the modulated signal picked up by the active device.

RFID technology was developed in 1983 by Charles Walton. Sony and Philips agreed to establish a compatible specification and this was approved as an ISO/IEC standard in 2000 (ISO/IEC 14443). The passive tags and cards used for RFID typically store between 96 and 8192 bytes of data, which can be read (and in some cases, written) using the RFID protocol.

Nokia, Philips and Sony established the NFC Forum in 2004. It is a non-profit industry association which promotes the implementation and standardisation of NFC technology to ensure interoperability between devices and services.

NFC provides the same functions as RFID but also allows for communications when both devices are powered. In this case, power is not transferred using the carrier and the two devices can exchange data in an ad-hoc peer-to-peer fashion.

The standard defining NFC is ISO/IEC 18092. This technology is now found in all manner of smartphones and other portable devices.

Sony's FeliCa RFID system includes dynamic encryption for increased security. It was considered as part of the ISO/IEC 14443 RFID standard but in the end, was not included. However, some of the principles used by FeliCa ended up being used as part of the later NFC standard.

Three different data exchange rates are in current use by NFC devices: 106kb/s, 212kb/s and 424kb/s. If an active device transfers data at 106kb/s, it uses modified Miller coding with 100% modulation. Miller coding is a type of Modified Frequency Modulation known as "delay encoding". This is similar to NRZ (non-return-to-zero) encoding but with less power radiated at lower frequencies.

For the higher data rates, Manchester coding is used, with a modulation ratio of 10%. Manchester encoding is another method of turning a bitstream into a symmetrical AC signal and is also used for transmitting digital audio data (S/PDIF).

Elecrow's NFC shield

The Elecrow ACS53201S NFC shield measures 69 x 53mm (including the loop antenna) and it plugs directly

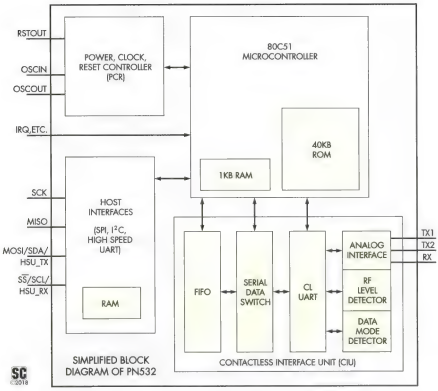


Fig.1: simplified block diagram for the PN532 controller IC. The chip is based around four sections: an NXP 80C51 micro (an old design!), NFC communications block, serial block and power/clock/reset controller.

into an Arduino Uno or Mega 2560, or one of the many compatible modules. It derives its power from the Arduino and even comes with a passive keyring NFC tag for testing (see lead photo).

At the heart of the shield is the NXP/Philips PN532 NFC controller IC. The internals of this IC are summarised in the simplified block diagram, Fig.1. It's based around an NXP 80C51 microcontroller (upper right), which includes 1KB of RAM (working memory) and 40KB of ROM (for storing the firmware).

The other main sections are the contactless interface unit or CIU (at lower right) which handles the actual NFC communication, and the host interface section at lower left which handles communication with the host computer or controller (in this case, the Atmel micro on the Arduino board).

The host interface section can be configured to communicate via SPI (serial peripheral interface), I²C (inter-IC serial communication) or a high-speed UART (HSU; ie, serial) connection. But note that the PN532 chip used in the Elecrow NFC shield has been configured for SPI only.

Fig.2 shows the full circuit of the Elecrow NFC shield, plus a block diagram of an Arduino host at upper left.

The PN532 device, IC1, connects to the NFC loop antenna at top right via the TX1, TX2 and RX pins and a network of passive components. These include inductors L1, L2 and various capacitors and a few resistors. These are used for impedance matching, to make the antenna resonant at the required frequency and to filter out unwanted signals.

IC1 uses 27.12MHz crystal X1 to generate its internal master clock and divides this by a factor of two to produce the NFC carrier frequency of 13.56MHz.

Although IC1 can operate from supply voltages of 2.7-5.5V, in the Elecrow shield it is powered from a 3.3V regulated supply. This is derived from the Arduino's 5V supply via REG1, an MIC5205-3.3 LDO (low dropout) regulator. This is separate from the 3.3V rail from the Arduino since IC1 can draw up to 200mA when transmitting, which could overload the regulator on the Arduino.

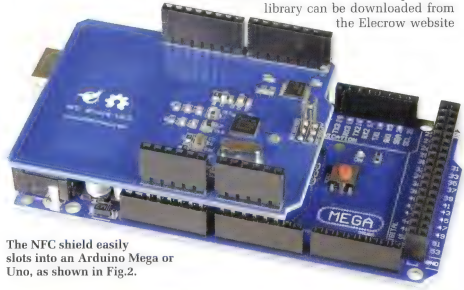
This means that level translation is necessary on the SPI signal lines between IC1 and the Arduino. That's provided by IC2, a 74LV4T125 quad buffer translator. Three of IC2's buffers are used to translate the logic levels of the MOSI, SCK and MISO signal lines, with the fourth buffer unused. IC2 is also powered from the +3.3V supply from REG1.

The only other components on the board are a number of bypass and filter capacitors for IC1, IC2 and REG1, a pull-up resistor on pin 38 of IC1 to enable it and a capacitor and resistor connected to the V_{MID} pin of IC1 (pin 9), which is used to DC bias its RX pin (pin 10) to half supply.

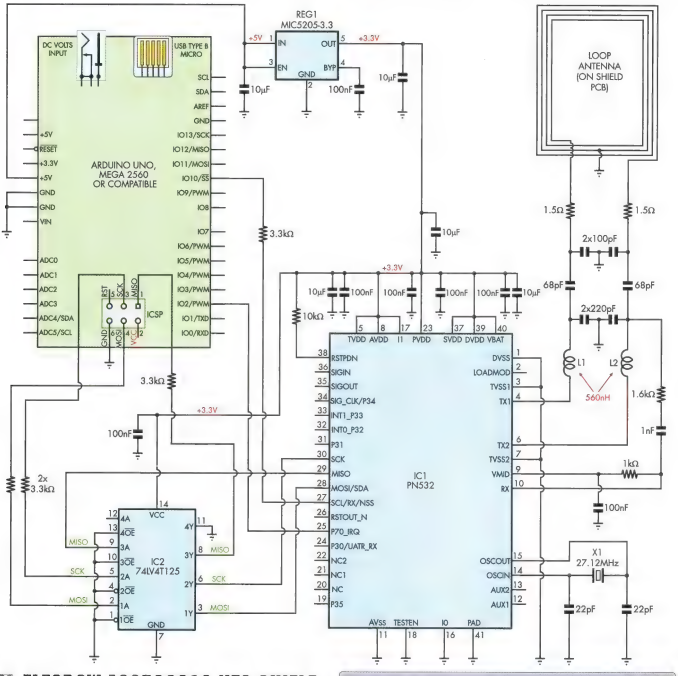
Note that Jaycar sell a similar NFC Shield, made by "linksprite" (Cat XC4542). While not identical to the Elecrow shield, it is compatible and we have tested it successfully with the same software.

Arduino software

Luckily Elecrow has made the software side of things quite easy by making available an Arduino library written specifically for communicating with the PN532 via the SPI port. The library can be downloaded from the Elecrow website

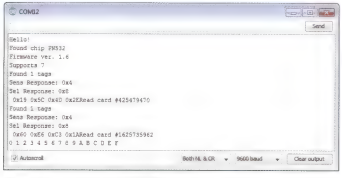


The NFC shield easily slots into an Arduino Mega or Uno, as shown in Fig.2.

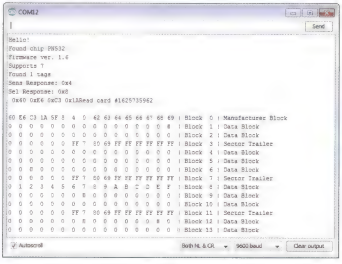


SC ELECROW ACS53201S NFC SHIELD

Fig.2: complete circuit diagram for the Elecrow ACS53201S near-field communication (NFC) shield, and wiring diagram for the shield with an Arduino, or similar, board.



Screen 1: using the readMiFareMemory.ino sketch reads and then prints the data from the RFID card and keytag.



Screen 2: the readAllMemoryBlocks.ino sketch reads the card's memory after writing 16 bytes into it (to block 8).

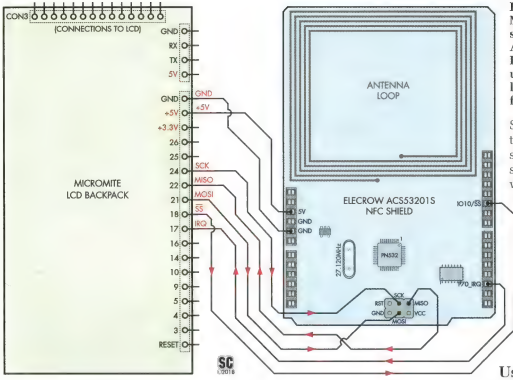


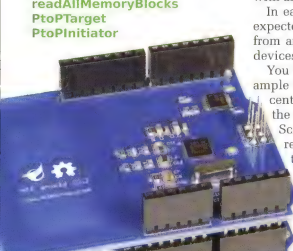
Fig.3: wiring diagram for a Micromite to the Elecrow NFC shield. We've converted the Arduino NFC library into a BASIC library so that you can use it with the Micromite. The library can be downloaded from the SILICON CHIP website.

in a zip file called PN532_SPI.zip (see Links panel).

This can be made available for use in the Arduino IDE by clicking on the Sketch menu and then on the Include Library → Add .ZIP Library menu option. Select the ZIP file that you have downloaded and it will be added to the IDE's library list.

The library comes with six example sketches, named:

writeMifareMemory
readMifareTargetID
readMifareMemory
readAllMemoryBlocks
PtoPTarget
PtoPInitiator



"Mifare" is another way of referring to passive NFC tags and cards. The "PtoP" part of the last two sketch titles is short for "peer to peer" and indicates that these sketches are used for NFC communication between two active devices.

I tried opening and running the first four of these example sketches with the Elecrow NFC shield connected to both an Arduino Uno and a Mega 2560. In each case, I tested it with both the keyring tag that came with the shield and also with an NFC card that came with another NFC/RFID reader.

In each case, it worked exactly as expected and I was able to read data from and write data to both passive devices with no problems.

You can get an idea of how the example sketches work from the adjacent screen grabs. Both grabs are of the Arduino IDE's Serial Monitor. Screen 1 shows the output when reading the card first and then the keyring tab, using the readMifareMemory sketch.

Screen 2 shows the results when using the readAllMemoryBlocks sketch to interrogate the card after using the writeMifareMemory sketch to write 16 bytes into the card's memory (to block 8).

The easiest way to build your own application using the Elecrow ACS53201S NFC shield would be to modify one of the example sketches. Or if you're doing something fairly complex (eg, which involves both reading and writing data), you may need to incorporate bits and pieces of the example sketches into your own sketch.

If you want to fully understand how to use the PN532_SPI library functions, it is simply a matter of studying the example sketches to see how they operate.

Using it with a Micromite

What if you want to use the shield with another MCU, like a Micromite? Since it has a standard SPI port, it's quite easy to make the required connections, as shown in Fig.3.

The software is a bit more tricky though since there was no Micromite library available to interface with the PN532 IC. So, we have translated the Arduino library into a Micromite BASIC file and have made this available for download from our website (free for subscribers).

We have also translated some of the example programs. The download package includes several BASIC files which all start with an identical set of library functions but have different sample code snippets at the bottom.

Having wired up the shield as shown in Fig.3, it's simply necessary to upload one of these programs to the Micromite and run it. You should see similar output on the Micromite serial console as shown in the screen grabs above.

Extra links

NFC Forum: https://nfc-forum.org/

PN532 data sheet: siliconchip.com.au/link/aakl

PN532 user manual: siliconchip.com.au/link/aakm

How to use the PN532: siliconchip.com.au/link/aakn

Elecrow shield library: siliconchip.com.au/link/aako SC

PICkit Turns Four!

A couple of months ago, we featured an advert for the new PICkit 4 in-circuit programmer and debugger from Microchip. We've long been a fan of the PICkit and finally, we got our hands on a "4". What did we think of it? Well, here's a clue: it's not going to be sent back in a hurry . . .

"Hands on" review by Tim Blythman

The first thing I noticed upon unpacking it is that the PICkit 4 is slightly wider and thicker than the PICkit 3. It has an 8-pin in-circuit serial programming (ICSP) header instead of a 6-pin header like the previous version and strangely, I couldn't see any buttons or indicator LEDs adorning the device (but I figured out where they are hidden later, as you will soon read).

On the side of the unit, there is a MicroSD card slot, presumably for programmer-to-go function. This allows you to reprogram a PIC when you don't have a computer at hand. I also noticed that the USB socket has changed from the mini socket on the PICkit 3 to a micro socket on the PICkit 4.

What you get in the box

Besides the unit itself, there's nothing else in the box except for a USB Type-A to micro-B cable (around 1.2m long) and a small sheet of PICkit 4-themed stickers. The back of the PICkit 4 has a "Get Started" URL listed (microchip.com/pickit4). Interestingly, the logo on the PICkit 4 boasts that it is an in-circuit debugger; I hope it can program PICs too!

I opened up the web page mentioned and found a product page with a list of specifications and features.

Of particular interest to me is the "silicon clocking speed match" feature, which allows it to automatically select the highest possible programming speed for a given PIC. The same page also states that the PICkit 4 supports the JTAG and Serial Wire Debug protocols.

The Quick Start Guide (which can be downloaded from the aforementioned product page) indicates that the two extra pins on the connector are used in JTAG, Serial Wire Debug, UART CDC and SPI modes.

This suggests that the PICkit 4 may be able to provide serial communications while connected to a PIC; something that the PICkit 3 did not support.

The PICkit 4 can supply power to the target device from the USB host; the voltage is adjustable to suit different PICs. It can also program chips running off their own power supply.

When used in "programmer-on-the-go" mode, the PICkit 4 must be powered from a USB power source such as a battery bank.

The instructions mention the future possibility the device being powered from the target board but that will require a firmware update. As expected, the microSD card is used to load the firmware in this mode.

You press on the PICkit 4 logo to initiate programming in this mode. Is it a magic logo, perhaps?

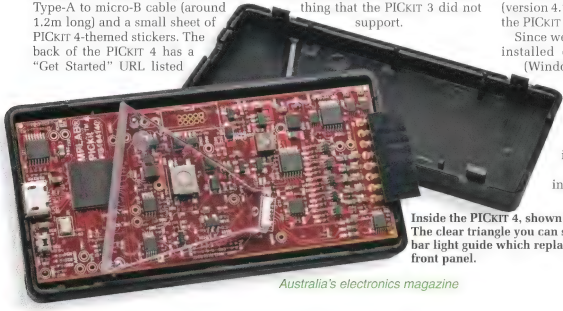
No, the logo conceals a tactile switch, which has a distinctive action when pressed.

Software and setup

The MPLAB X IDE/IPE software (version 4.15 or later) is needed to use the PICkit 4.

Since we already had that software installed on our Windows 10 PC (Windows 7/8, macOS and Linux are also supported), we simply we plugged it into our PC to try it out.

Once plugged in, it becomes obvious that the indicator LEDs are hidden. Just like the switch, the indicator LEDs shine through



Inside the PICkit 4, shown here about twice life size. The clear triangle you can see left and centre is a LED bar light guide which replaces individual LEDs on the front panel.

a light guide, with a purple stripe appearing above the logo, which soon turns blue.

At the time of this review, we were working on the Super Digital Sound Effects Module, for which we were using a PICkit 3.

We swapped it out for the new PICkit 4 and selected the new programmer for the project.

Programming the device for the first time involves updating the PICkit's firmware to suit the type of PIC being programmed, so we let that happen.

Interestingly, the console output for the firmware upgrade notes that the FPGA version is ff.ff.ff.

Does it have an FPGA or can it program FPGA's? We'll have a look when we open it up later.

Some users report that the PICkit 4 stores multiple firmwares onboard, so the tedious process of the PICkit 3 slowly updating its firmware when changing between target microcontrollers should be a thing of the past.

In use

Programming a chip with the PICkit 4 is noticeably faster than with the PICkit 3; it took about 1.5s to erase and program the PIC32 in our Sound Effects Module, compared to around eight seconds for the PICkit 3.

Having said that, the IDE software (written in Java) still spends another six seconds connecting to the programmer and checking its firmware before it will initiate programming.

The LED stripe on the unit turns green while programming.

Like the PICkit 3, the PICkit 4 is also capable of in-circuit debugging (see explanatory panel) but the new version makes this much snappier. The older unit took a few seconds to resume from a breakpoint while the PICkit 4 takes half a second or less.

This is one of the biggest improvements to our day-to-day use of this tool, especially since we can now step over a few instructions quickly without setting extra breakpoints.

We also found that the PICkit 4 is able to set breakpoints practically instantly, while the target is running (although the target software appears to pause briefly).

This is great for bringing debugging closer to a real-time experience.

Interestingly, there's a speed option (under Program Options/Program Speed) that by default is set to "nor-

Comparison between PICkit 4, at 90 x 43 x 19mm and the PICkit 3, 95 x 40 x 11mm. The other obvious difference between the two is the apparent lack of LEDs and pushbuttons on the PICkit 4 – the blue bar on the 4 actually changes colour in use, while pressing the logo triggers a tactile switch.

What's inside?

The big news is that the latest and greatest PIC programmer is not powered by a PIC microcontroller, but in fact a 32-bit 300MHz Atmel SAM E70. The internal ISP header looks like the standard AVR 10-pin variant. Of course, Microchip has owned Atmel for two years, so it's not surprising they would pick the best of both worlds.

That's not the only IC, as there appears to be around fourteen 'large' ICs, plus numerous smaller ones around the board, and nineteen test points. Based on this circuit's complexity compared to the PICkit3, it looks like this PICkit might be a bit harder for the cloners to replicate.

The PICkit 4 appears to be a close relative of the ICD4 In-Circuit Debugger, which also sports a SAM E70 and an FPGA for 'faster communication, downloads and debugging', so it appears the FPGA forms part of the high speed USB interface for these parts.

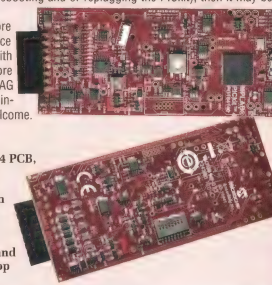
There's an MCP4452 quad I2C digital potentiometer near the ICSP header, presumably used for VPP voltage control, and two MIC2042 power switch IC's on board. These are rated at 3A, so may be used for VPP generation. There's another digital potentiometer and a number of op-amps around the board.

The IO pins of the ICSP header have substantial networks surrounding them, suggesting a high degree of protection.

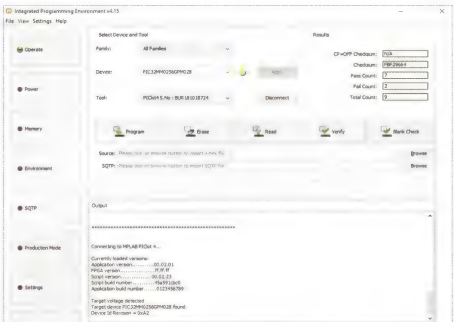
The light pipe covers much of the board, and appears to be held in place by what looks like a flexible flat cable connector, but is actually an RGB LED module, pointed into the light pipe. The back of the PCB where the pushbutton is mounted has case support preventing the PCB from flexing excessively. Still, pushing the button requires flexing the front of the case and seems like it takes more force than necessary.

Next to the USB socket is a small hole in the case which corresponds to a small edge mounted tactile switch marked SW2 on the PCB, which apparently puts the SAM E70 into bootloader mode, after which you should use the 'Hardware Tool Emergency Boot Firmware Recovery' from the Debug menu in MPLAB X. We wouldn't recommend pushing this button for the sake of seeing what it does, but if the PICkit 4 isn't recognised by your computer (even after rebooting and or replugging the PICkit), then it may be an option.

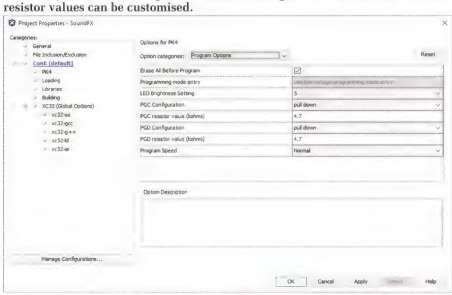
The PICkit 4 packs a lot more in than it appears to need, hence the slightly larger case, but with pending support for many more features, possibly including JTAG and AVR ISP and a pleasing increase in speed, it is certainly welcome.



The two sides of the PICkit 4 PCB, removed from its case and with the LED bar indicator removed for clarity (it sits in the angled white socket on the photo above. Other connectors of note are the large I/O socket on the left and the USB socket (right side top photo).



The 'Program Options' section of the PICkit 4 configuration has many more options than that for the PICkit 3. In case it is too bright, the LED brightness can be adjusted (with a range of 1 to 10, defaulting to 5), and the PGC and PGD resistor values can be customised.



mal" but can also be set to "high" or "low".

So if the already faster experience isn't good enough, there's an even faster option.

Some teething problems

One small problem we discovered is that the Hold in Reset/Release from Reset option in the MPLAB X IDE no longer works.

We found that we needed to disconnect the VPP line between the PICkit 4 and the target circuit to allow the circuit's MCLR pullup to get the target out of reset.

Apparently, this is a software bug which has been rectified in MPLAB X v4.20.

So if you purchase a PICkit 4, you should make sure to upgrade to the latest version of MPLAB X to avoid this sort of bug.

We also found that we occasionally would get a "Connection Failed" message during programming but this was usually overcome by unplugging and replugging the USB cable from the computer.

We have seen similar behaviour from the PICkit 3 in the past. It may be due to the relatively high power demand of the unit when it's also powering the target circuit.

Interestingly, the PICkit 4's LED remains lit when the cable USB is disconnected. It appears the "power programmer from target" setting is active by default, causing the PICkit 4 to draw power from the target when it has no USB supply.

From the notes in the quick start guide and links, it's apparent the current version of the firmware (supplied with MPLAB) is not quite complete. For example, the Programmer-To-Go support is currently listed as "Feature will be added with a firmware upgrade".

The Microchip forums suggest that this will be added in the August release of MPLAB X. See: siliconchip.com.au/link/aakx

The Microchip website also has the following comment:

"Currently, the MPLAB PICkit 4 In-Circuit Debugger/Programmer supports many but not all PIC MCUs and dsPIC DSCs, but is being continually upgraded to add support for new devices."

With this being the first release of a

Comparison of PICkit family

	PICkit 1	PICkit 2	PICkit 3	PICkit 4
Release	2003	2005	2009	2018
ICSP Header	No	6 pin	6 pin	8 pin
UART tool	No	Yes	No	Yes*
Programmer-To-Go	No	Yes (128kB)	Yes (512kB)	Yes*
Programmer-To-Go Storage		EEPROM (upgradeable)	EEPROM	Micro SD Card
Main Controller IC	PIC16C	PIC18F	PIC24	SAM E70
Interface	USB	USB High Speed	USB High Speed	USB High Speed
Clones available	-	Yes	Yes	-

** some features of PICkit 4 are not currently available, but are planned for future firmware updates*

In-circuit debugging

One of the biggest advantages of using micros from Microchip is the near-universal support for in-circuit debugging (ICD).

If you have had to debug a complex program running on a microcontroller with only a serial console (or in some cases, not only that) you will know how frustrating it is to not know what is going on inside the program.

You end up having to add a lot of extra print statements, temporarily remove sections of code and constantly re-flash the microcontroller until you can figure out what's going wrong.

All of that pain can be avoided by using in-circuit debugging. The main thing you need to do so that you can use this feature is to ensure that the programming pins do not share their functions with any other hardware that may interfere with the debugging signals.

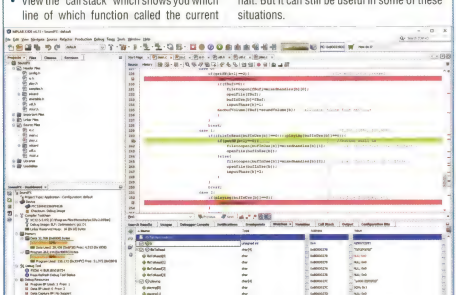
You also need to compile the project in debug mode, which normally uses less aggressive speed/size optimisations.

Once you have done that, you can set "breakpoints" on just about any line in your software and when you start the debugging session, the program on the PIC will run until it reaches one of these breakpoints. It will then stop and the code surrounding that line will be shown on the screen (see screen grab below). You then have the ability to perform the following actions:

- Inspect the state of all the variables at this point in the execution of the program. That includes global variables and those local to the function containing the breakpoint.
- View the "call stack" which shows you which line of which function called the current function and so on, up to the entry point function (normally "main").
- Inspect the state of the PIC's RAM, its control registers and so on. Basically, you have full access to a snapshot of the PIC's state at that point in the code's execution.
- "Step" through the code one line at a time and see which order the statements are processed (which will depend on any loops, if statements, function calls etc which are encountered).
- See how variables and other processor state changes as the program progresses. In fact, variables, registers or memory that you are "watching" will be highlighted in a different colour when the state changes for any given step.
- Change breakpoint locations, including deleting existing breakpoints or setting new ones, and then allowing the code to continue execution until it encounters another breakpoint. In fact, one valuable aspect of in-circuit debugging is the ability to set a breakpoint and see whether the code on that line is ever reached.

This should give you an idea of how much easier it is to diagnose and fix complex faults in the software using ICD compared to other techniques. The fact that the PICkit 4 makes it faster is a great benefit.

It's difficult to use ICD to diagnose timing-sensitive problems as debug mode changes program timings and any time the program is frozen (eg, when encountering a breakpoint), real-time tasks running in the processor also halt. But it can still be useful in some of these situations.



The in-circuit debugger being used on the Super Digital Sound Effects Module. Three breakpoints have been set. The code is paused on the second breakpoint and the bottom window ("Watches") shows the value of monitored variables.

PICkit since the merger of Microchip and Atmel and with the extra pins on the ICSP header, users will be curious as to whether it can program Atmel parts such as AVRs.

This too appears to be a future capability, with support still to be added to MPLAB X.

Interestingly, the 8-bit AVR family appears to be available as an option in both the current IDE and IPE, although no actual parts are available for selection.

Conclusion

As far as we're concerned, the PICkit 4 does what we need it to do, ie, it programs and debugs PICs, and it does both much faster than the PICkit 3 did. So we feel that the hardware improvements makes the cost of upgrading well worthwhile.

If you're hoping to program AVRs or use the programmer-to-go function, you may want to wait until the software is ready to pull the trigger.

You should also check that the PICkit 4 has software support for the PICs you intend to use, in the latest version of the MPLAB X software, so, check which version of MPLAB X you'll need. SC

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Guitar preamp with JFETs to emulate valve sound

I have designed and built a number of solid-state guitar preamps/amplifiers, using various common techniques to achieve the sound characteristics desired by guitar players.

These methods commonly involve the use of signal diodes, zener diodes, selected and/or modified op amp configurations etc to shape the audio signal into something acoustically pleasing.

Then recently I found a paper published by Dimitri Danyuk at an Audio Engineering Society (AES) conference in 2004 (siliconchip.com.au/link/aakq).

It describes how Field Effect Transistors (FETs) can be configured to emulate the sound of a triode (valve) amplifier stage, eg, the ubiquitous 12AX7 which is (very) widely used in various makes and models of guitar amplifiers.

FETs are generally used in this role, rather than Bipolar Junction Transistors (BJTs), because like valves, they have a high-impedance control terminal (the gate in a FET or the grid in a valve). But the FET transfer characteristic (ie, the relationship between input and output voltages) is more like that of a pentode (eg, EF86) than a triode.

And if we use JFETs (inherently depletion-mode) rather than Mosfets (inherently enhancement-mode) then they have the same property as valves where they conduct current until the control terminal is pulled negative, at which point they begin to "cut off".

Danyuk's system relies on applying negative feedback from an unbypassed source resistor to turn the x^2 transfer characteristic of a JFET into the $\sqrt[3]{x}$ transfer characteristic of a triode. However, it does require the feedback to be precisely matched to the JFET's gate switch-off threshold which unfortunately varies dramatically between devices of the same type.

That is likely why this technique is not widely used in commercial equipment. Their parameter spread is often too wide for most mass-manufacturing systems and the (labour) cost of individually selecting, adjusting and/or aligning these devices is simply not economically viable.

Fortunately, labour costs are not something that most hobbyists worry about and you only need a multimeter, a battery and a couple of resistors to measure the gate-to-source cut-off voltage (V_{GS}) and the saturated drain current (I_{DSS}) of various JFETs. The test circuit is shown below.

Using this set-up, I measured several 2N5457, 2N5458 and 2N5459 JFETs and found that their parameters varied widely between different samples.

But then I sourced some 2SK-series Toshiba JFETs where the grading job has at least partly been done by the manufacturer. Each of the FET types, eg, a 2SK30 has a suffix (the letters Y and GR in this case) indicating the range in which the I_{DSS} of the FET falls.

Having measured a particular JFET, we can calculate the required source and drain resistances to provide the triode characteristic (the units are volts, ohms and amps):

$$R_S = 0.83 \times (V_{GS} \div I_{DSS})$$

$$R_D = 0.9 \times (V_{CC} - 2 \times V_{GS}) \div I_{DSS}$$

You can also use the online calculator at http://siliconchip.com.au/link/aakp For example, if we consider a 2N5457 with a V_{GS} of 0.8V and an I_{DSS} of 3.5mA, for a 20V supply, we get R_S = 180Ω and R_D = 4.7kΩ.

The online calculator also tells us the quiescent drain current is 1.5mA. I have selected 20V for V_{CC} so that we can use a 24V supply with an RC filter to prevent supply ripple from coupling into the audio signal, allowing for a 4V drop across the filter resistor.

So we need a decoupling resistor of 4V ÷ 1.5mA = 2.7kΩ along with a sufficiently large bypass capacitor to give the filter a -3dB point well below 50Hz (say, 100µF).

The circuit opposite shows a guitar preamp designed using this technique. It broadly follows the layout of a VOX AC-30 guitar preamplifier.

It uses a scaled version of the VOX tone controls (which in turn are drawn from the classic FMV circuits) – including the switchable "top boost" facility but excluding the high cut control, which I have omitted for simplicity.

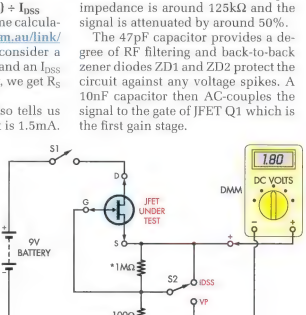
It has conventional "HI/LO" input options to suit different instruments and provides a line-level output suitable for connection to an external amplifier or it could be built with an integral guitar amplifier. It works as follows.

Circuit description

The signal is fed in via either CON1 (high impedance/low level) or CON2 (low impedance/high level). If fed in via CON1, the effective series resistance is 34kΩ and the input impedance is around 600kΩ || 47pF.

If fed in via CON2, the effective series resistance is 68kΩ, the input impedance is around 125kΩ and the signal is attenuated by around 50%.

The 47pF capacitor provides a degree of RF filtering and back-to-back zener diodes ZD1 and ZD2 protect the circuit against any voltage spikes. A 10nF capacitor then AC-couples the signal to the gate of JFET Q1 which is the first gain stage.



The value chosen for the 1.5MΩ gate bias resistor intentionally sets the bass -3dB roll-off point to around 50Hz, in conjunction with the 10nF coupling capacitor.

Q1 has source and drain resistors calculated as described above; you will need to change their values to suit your device and the supply voltage, if different from the 24V rail shown (reduced to 20V by the supply filter).

The output of this first stage, at the drain of Q1, is AC-coupled to potentiometers VR1 and VR2 which are the volume controls in the "normal" and "top boost" modes respectively. The lower-value coupling capacitor for VR2 is responsible for the "bright" sound in the top boost mode.

The signal fed to the rest of the preamp comes from either the wiper of VR1 or the wiper of VR2 depending on the state of DPDT relay RLY1 which is controlled using switch S1.

This allows a foot switch to be used, which is connected in parallel with the onboard switch. LED1 or LED2 lights to show the current mode.

The selected signal is then fed to the gate of JFET Q2, the second gain stage. The resistor values surrounding this FET are calculated as above but allow for different FET characteristics and a higher supply voltage as no decoupling is used here.

The signal from its drain is then AC-coupled to the gate of JFET Q3 via a 100nF capacitor. This is set up as a source-follower to provide a low source impedance for the tone control section.

The resistor values for Q3 are calculated as above but the "drain" resistor is instead moved to be between the source terminal and the source resistor, with the gate bias connection being the junction of the two resistors as shown below.

The tone control network is a passive (ie, not feedback) type but works quite well. Keep in mind that while the response is not particularly flat, this is not a hifi amplifier so that isn't important.

Another gain stage follows the tone control network and JFET Q4 is configured in essentially the same manner as Q2.

The signal from this stage is then fed to source-followed Q5 which is configured virtually the same as Q3. This provides a low source impedance for the final volume control potentiometer, VR5.

Having a volume control at the output means that VR1 and VR2 can be wound up to drive the intervening stages into clipping, adding distortion, while VR5 can be wound back to produce the required sound level.

The power supply uses a simple adjustable regulator to provide the 24V rail but a 7824 fixed linear regulator could also be used. This is fed from a ~30V rail which would come from the rectified and filtered output of a small transformer with a 24VAC secondary.

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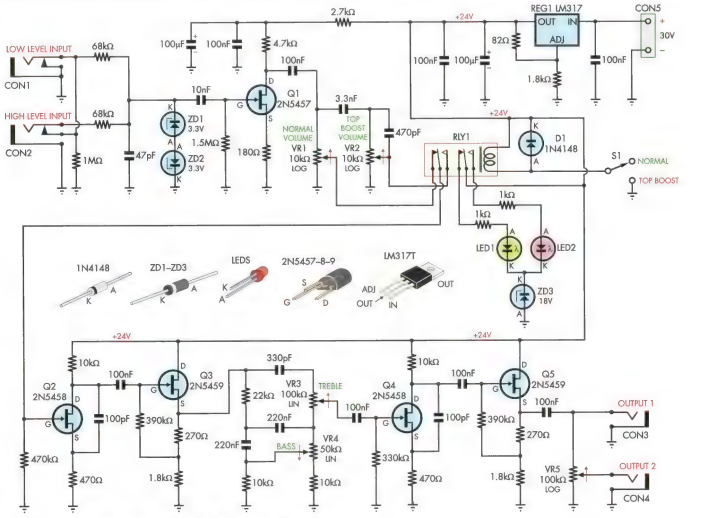


JFET GUITAR PREAMPLIFIER

Guitar preamp with JFETs

The wiper of the final volume control pot connects to output socket CON4, to be fed to an external power amplifier.

You could build the preamp into the same cabinet as the power amplifier and wire it up permanently.

I typically build preamplifiers like this with amplifiers ranging from 30 to 100 watts.

I prefer to use Mosfet power stages with an output transformer, a similar configuration to that used in the old pentode amplifier designs.

Graham Bowman,
Perth, WA. ($100)

The Coober Pedy Opal Miner Game

Our opal miner is underground at Coober Pedy when the mine lights start to flash on and off; it could be a problem with the generator.

To reach the generator, the miner must climb a ladder to the top of the shaft. But trying to climb when the lights are out will surely result in a fall. So the miner must make use of the short periods when the lights are on to make upwards progress!

The ladder is represented by a 10-segment LED bargraph. You must press the climb button several times to move up the ladder one step but you can only do this when the light (LED1) is on.

If you press the button when the light is off then you will start to slip back down the ladder, one rung each time you press the switch while in the dark. So climbing is slow but falling is quick.

The difficulty of the game can be adjusted by altering the length of the periods when the light (LED1) is on. There are ten different difficulty levels and you can select them as described below.

The aim of the game is to climb to the top of the ladder as quickly as possible. When you finally reach the top of the ladder, your reward will be a lovely rendition of the Muppets theme song, played back using a piezo buzzer to mark your achievement. If for some reason you don't like this song, the software includes several others that you can try out.

This game is built around a PICAXE-20M2 microcontroller (IC1). The circuit has been deliberately kept simple. IC1 drives the ten anodes of the LED array segments directly from its B0-B7 and C0-C1 digital output pins.

The cathodes have a common connection to a 330Ω current-limiting resistor to ground. Only one resistor is needed since only one segment is lit at a time.

The light (LED1) is also driven directly from a digital output pin, in this case, C3, via another 330Ω current-limiting resistor. A 10kΩ pull-up resistor normally keeps digital input pin C2 high but when the climb button (S1, a tactile or snap-action pushbutton) is pressed, it brings C2 low and this is detected by the BASIC software and the appropriate action is taken.

Sounds are produced by piezo transducer PT1 with the frequency determined by the square wave produced at digital output pin C7 (pin 3) of IC1. You will hear a single beep as the game starts, in addition to the song being played each time the player reaches the top of the ladder.

Power is from a 6V battery (eg, four AA cells) and a power switch (S2) and reversed polarity protection diode (D1) are included. D1 also reduces the battery voltage to around 5V to suit IC1. The 5V supply rail is stabilised with 47µF and 100nF bypass capacitors. You can switch S2 off and then on again at any time to reset the game.

The prototype game was housed in a medium-size Jiffy box with the parts mounted on a DIP-pattern stripboard. S1 and S2 need to be easily accessible while the ten-segment LED display and LED1 need to be clearly visible.

Suitable LED array modules are the Altronics Cat Z0964 and Jaycar Cat ZD1704. Alternatively, you could use ten individual LEDs of any colour. For PT1, I suggest you use either Altronics Cat S6140 or Jaycar Cat AB3440.

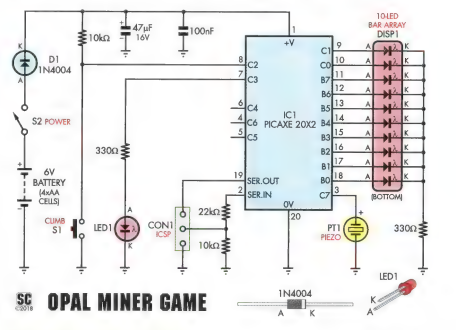
The circuit includes an in-circuit serial programming (ICSP) header to load programs into IC1; which uses pin 2 for serial input and pin 19 for serial output. You will need a PICAXE-compatible USB programming cable and the free "program editor software" from the PICAXE website to load the software.

The BASIC source code is named "opal_miner_20m2.bas" and can be downloaded from the Silicon Chip website, free for subscribers.

To change the difficulty level, hold down button S1 while switching on the power using S2. One of the LED segments will light to indicate the difficulty level, with the bottom-most segment indicating the easiest setting and the top-most the hardest. It will automatically progress from easiest to hardest. Release S1 and the currently indicated difficulty level will be made the default.

This is stored in EEPROM so it will be retained even after power is switched off. Use the same procedure again to change it.

Ian Robertson,
Engadine, NSW. ($70)



Empty tank warning indicator

If you have an underground tank with a pump to empty it, such as a fuel tank or septic tank, it may not be obvious when you have run out of liquid to pump out.

We ran into this problem on our boat, which like most large yachts has a stainless steel holding tank (130 litres) with an effective "full" indicator but no indication for "empty".

It is emptied by a purpose-designed 12V diaphragm pump (somewhat slowly). Because it takes so long, we need some warning once the tank has been emptied and we didn't want to drill any holes in the tank (for obvious reasons!).

The simplest solution I could come up with was to monitor the current drawn by the pump motor since it drops when the pump is pumping air rather than liquid.

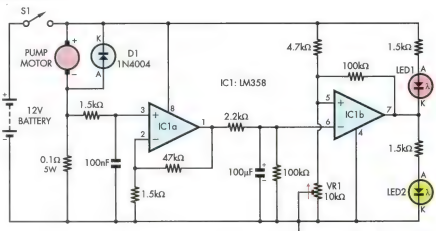
This was achieved by simply connecting a 0.1Ω 5W shunt in series with the motor and then connecting the circuit shown here to light one of two LEDs based on whether the pump's load current is above or below a threshold.

The pump current varies considerably because of the variable loading placed on the internal cam of the diaphragm pump. In our case, the loaded pump amperage varies from 1.6-3.0A, typically averaging about 2.5A. When unloaded, the current drops to 0.8-1.5A, averaging around 1.2A. So in our case, the threshold is around 1.5-1.6A.

The circuit presented here monitors the pump current and lights a red LED (LED1) if the current is above the threshold, indicating that there is still liquid in the tank. If the current is below the threshold, it lights a green LED (LED2) instead, to indicate that the tank is likely empty.

It works as follows: current flowing through the motor must also pass through the series 0.1Ω resistor and so a voltage is developed across this resistor, ie, 0.1V/A.

This voltage then passes through an RC low-pass filter (1.5kΩ || 100nF) with a -3dB point of 1kHz, to remove commutator spikes and so on.



TANK EMPTY INDICATOR

Single-supply op amp IC1a then amplifies this voltage by a factor of 32.3 times (47kΩ ÷ 1.5kΩ + 1). The amplified signal is then low-pass filtered again, this time with a -3dB point of around 1Hz. This provides some averaging for the motor current reading. This voltage is then fed to the inverting input (pin 6) of IC1b, the other half of the dual op amp, which is used as a comparator.

Its pin 5 non-inverting input is biased to a reference voltage which is derived from the 12V supply via a resistive divider and the voltage can be adjusted using trimpot VR1. This is set to provide the required threshold. In our case, this will be close to 5V (since 1.5A × 0.1Ω × 32.3 = 4.85V).

When the amplified signal voltage at pin 6 is higher than the reference voltage at pin 5, the output of IC1b goes low, sinking current through LED1. When the voltage at pin 6 is lower than at pin 5, the output goes high, sourcing current to LED2.

Even though the normal motor current can be pretty close to the threshold current, the circuit does not toggle rapidly between lighting the two LEDs. That is partly because of the hysteresis provided by the 100kΩ feedback resistor from the pin 7 output of IC1b to its pin 5 non-inverting input and partly due to the low-pass filtering at its pin 6 input, which prevents brief current transients from affecting the operation.

The hysteresis works by slightly increasing the reference voltage at pin 5 when the output of IC1b is high since a small amount of extra current flows into the junction of the resistive divider that generates the reference voltage. That increases the amount by which the voltage at pin 6 must rise before output pin 7 switches low again.

Note that when the tank is nearly empty, since wind and waves can cause the boat to rock, the liquid inside will slosh around and that will cause LED1 and LED2 to alternate. But it isn't until the tank is completely empty that green LED2 is solidly lit.

The only problem I had with this circuit is that sometimes green LED2 will light continuously when I switch on the pump with a full tank. This turned out to be due to a blockage or an air bubble trapped within the pump or the pipes feeding it.

Toggling the pump on and off a couple of times will normally get rid of the blockage and give a correct indication that the tank is full.

Colin O'Donnell,
Adelaide, SA.

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We will pay good money to feature it in Circuit Notebook. We can pay you by electronic funds transfer, cheque or direct to your PayPal account. Or you can use the funds to purchase anything from the Silicon Chip Online Store, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au

Ekco Gondola 5-valve mantel radio

Ekco's Gondola set is keenly sought after by collectors because of its distinctively styled cabinet. But its circuit is very simple, resulting in a very spartan under-chassis layout. That makes it easy to work on – but this particular set was a wreck and needed a lot of restoration.

This radio was purchased from a fellow member of the Historical Radio Society of Australia who commented at the time, "I don't think that even you can bring this one back".

For me, there could be no greater challenge. It was a wreck but potentially, at the end of it all there was promise of another attractive mantel set for my collection.

The advertisement featured in this article from 1958 gives an insight into the market it was intended for. The radio pictured in the advert is tinted Florentine wine although the illustration does not depict the true colour. In reality, Florentine wine was a deep purple (burgundy), a common offering in the late 1950s from all major radio manufacturers.

My set for restoration was manufactured as the colour Café Tan and other colours were Adriatic Gold, Italian Ivory, Venetian Grey, Mediterranean Pink, Rome Red, Grotto Green, and Sorrento Jade.

These new brightly coloured plastics brought life into previously drab (cream) kitchens of the 1950s (for perspective, watch the first episode of the ABC series hosted by Annabel Crabb: "Back in Time for Dinner").

At a price of £26.5s, the Ekco Gondola mantel radio was aimed at middle-class housewives who aspired to giving their homes a "decorator touch". Accordingly, we see a cheery woman with an oar, rather than a gondolier, next to the radio. The raised bow and aft ends of a gondola are incorporated into the design theme of the radio's cabinet, justifying the claim "Inspired by the sweeping lines of Venetian gondolas".

It was made by Australian Electrical Industries, who also manufactured a wide range of electrical whitegoods under the brand name Hotpoint.

Fig.1 shows the details of the 5-valve circuit which is a conventional superhet. The local oscillator circuit feeding into the 6BE6 is a Hartley configuration using a tapped coil tuned by one gang of the tuning capacitor. The output load at the plate of the 6BE6 is the first IF transformer, IFT1, tuned to 455kHz.

Its secondary feeds the grid of the 6BA6 IF amplifier which drives the second IF transformer, IFT2. The top of its secondary is connected to pin 6 of the 6AV6 detector and audio amplifier. The bottom of the secondary is connected to pin 5 via a 5.6MΩ resistor. These two pins are the anodes of the two diodes in this valve.

The diode at pin 6 is the demodulator and the audio output appears at the bottom of the secondary of IFT2. It is filtered by capacitor C12 and fed to the volume control R5 via resistor R4. From there, the audio signal is tapped off by the wiper of R5 and fed via ca-

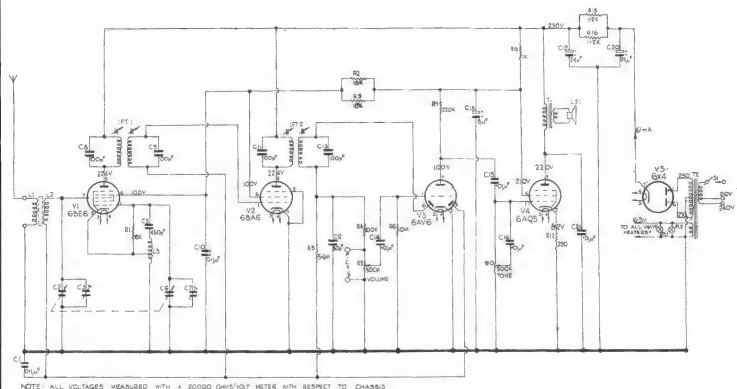


Fig.1: the circuit of the Ekco Gondola is a basic superhet with a very low component count. Note that pin 5 of the 6AV6 is a tiepoint for the 5.6MΩ resistor R8. The associated diode with pin 5 performs no signal detection.

pacitor C15 to the grid of the 6AQ5 output pentode. Capacitor C16 and potentiometer R10 provide a simple treble cut tone control.

The demodulated output of pin 6 of the 6AV6, appearing at the top of secondary of IFT2 is also used to derive the AGC voltage.

It is filtered by the above-mentioned 5.6MΩ resistor and the 0.1μF capacitor C1. The AGC acts on the grid of the 6BE6 via the secondary of the aerial coil and on the grid of the 6BA6 via the secondary of IFT1.

That being the case, what part does the diode at pin 5 of the 6AV6 valve play?

In fact, it does nothing. The pin 6 diode both demodulates the audio and generates the AGC voltage. It connects the "top" end of the IFT2 secondary to ground when that end is positive, which means that the "bottom" end of the secondary assumes a negative DC level – the demodulated audio and the AGC voltage.

The pin 5 diode is merely used as a connection point for the 5.6MΩ resistor. Typically other sets using the 6AV6 use one diode to do demodulation and produce the AGC and connect the second diode to chassis.

The final valve in the signal path is the 6AQ5 pentode. It is running in Class-A to drive the audio output transformer and there is no negative feedback around the stage. Interestingly, the loudspeaker impedance is only 2.5Ω.

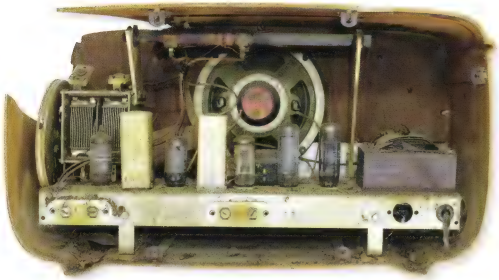
The power supply is also quite basic, with the 6X4 full-wave rectifier having only two 24μF electrolytic capacitors (C19/20) with paralleled 1.2kΩ resistors (R15/16) instead of filter chokes, as would have been the case with earlier sets.

This very simple circuit is evidenced by the spartan under-chassis layout. It almost looks as though half the point-to-point wiring and passive components are missing; they are not.

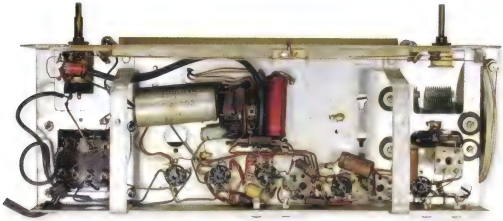
Electrical restoration

The first task was to remove the rather sad and sorry cabinet. While the topside of the chassis was pretty dirty in appearance, the underside was quite clean.

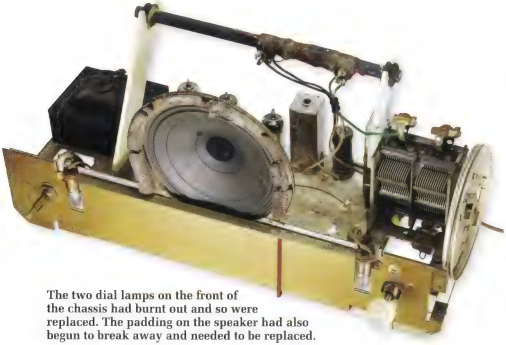
The plastic case had seen better days, and the dial had minor fractures.



The interior of the case was littered with leaves, dirt and who knows what else that had managed to find its way inside.



▲ At lower left, the 2-core mains wire is anchored by a knot in the chassis. This was replaced with a properly anchored 3-core cable.



The two dial lamps on the front of the chassis had burnt out and so were replaced. The padding on the speaker had also begun to break away and needed to be replaced.

Fortunately, most of the small capacitors were Ducon Styroseal type with polystyrene dielectric (manufactured at the huge Ducon plant in Villawood, Sydney). To this day, they are noted for very high insulation resistance (typically around $10^3\Omega$) and certainly did not need to be replaced.

Only three electrolytics are used in the entire circuit and these did need replacement. Two of the wax-impregnated paper capacitors (C1/10) were also replaced.

The original 2-core mains flex was anchored by a knot inside the chassis; that's the crude way it was done in those days.

This was replaced by a 3-core cable which has the benefit of providing an earthed chassis. The new cable was properly secured to the chassis when it was installed, as this is good practice.

The two blackened dial lamps were replaced and then it was to time switch on without the valves being installed. All was well so the valves were fitted. The next power-up showed stable power consumption of around 43W, as expected from the service manual

But nothing could be tuned in. Touching the pick-up input at the rear of the chassis produced a healthy hum from the speaker so the audio section seemed to be fine. When measuring the plate voltage of the 6BE6 mixer, an encouraging crackle was produced from the speaker when a prod was applied.

There are not a great number of possibilities for failure before this point, but Murphy's law ensured that I took the longest route to finding the answer.

The 6BE6's control grid measured 0V and was subsequently found to be shorted to earth. Well, that would clearly explain the non-performance of the radio.

My first suspect for the earthing was a connection between the two coils on the ferrite rod but isolating the connections showed no short. The second suspect was a short between the secondary of IFT1 and the metal case. Again, isolating the secondary showed no shorts to earth.

Looking at the circuit diagram of Fig.1 showed only two other logical possibilities; the tuning gang or its trimmer (C3). At a first glance the tuning gang's trimmer had been pushed down, although it was seemingly intact.

It took a closer sideways inspection

An aluminium sheet mould was clamped to the case, forming the template for the 2-part epoxy filler. Multiple applications of the epoxy filler were needed due to the curvature and thickness of the case.

to see that the trimmer adjustment screw had been pushed into the tuning gang and had shorted the gang. The same impact that damaged the case probably pushed on the trimmer to short it.

After some judicious bending to remove the short, happiness prevailed. From that point, the radio performed pretty much as expected and its alignment was fairly close to being optimum.

Cabinet restoration

Who knows just how the cabinet had arrived at this sad state of dilapidation? Apart from being dropped or maybe having something dropped onto it, plenty of leaves and dirt had found their way into the radio through the non-original ventilation space.

Broken or missing knobs are relatively common for this model but encouragingly, the highly stained knobs were intact. They were treated to sustained ultrasonic cleaning and came up well.

The grille cloth was dirty and very greasy, possibly as a result of being used in a kitchen. Fortunately it came up like new after a detergent wash. The Ekco badge needed a touch-up with gold paint.

The empty case cleaned up well using automotive degreaser and then came the intellectual task of devising a repair strategy.

The complex sculpting of the missing section was the biggest challenge I had yet faced in repairing a plastic case. Taking a cast from the intact section was not the answer because the sides are mirror images.

The strategy was to cut and shape an aluminium sheet to overlap the edges of the breaks and provide the basic contour of the case. Then Araldite was used to glue the contoured plate in place inside the cabinet.

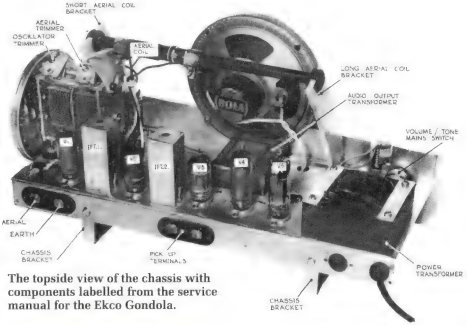
2-part epoxy car body filler was then applied in three major applications. Multiple applications were needed because of gravity. Much like preparing for pouring cement on a building site, form work was created for each of the front, top and side sections.

When mixed, the filler flows under gravity for about ten minutes before becoming viscous enough to hold shape. All sections were set proud of the final profile.

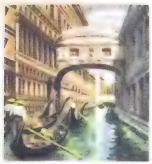
Initial shaping was done with an angle grinder, followed by finer profiling with abrasive papers. The intermediate result was a cabinet without the side-bar, just a smooth rounded contour.

A piece of MDF board (chosen because it has no wood grain) was profiled to create the side-bar then held in place with Araldite. Epoxy filler was added to blend the MDF with the cabinet. A Dremel shaping tool added the finishing touches to the contours.

The photograph showing the near-final case repair also shows some darker pink blotches. These blotches were created by the application of filler to the Swiss-cheese-like air holes that inevitably appear in the epoxy filler.



The topside view of the chassis with components labelled from the service manual for the Ekco Gondola.



VENEZIA

nspired by the sweeping lines of Venetian gondolas

... to give your home the "decorator touch"

New *mantel radio* "Gondola"

AEI EKCO

... in subtle, singing Mediterranean colours

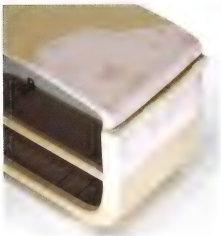
So new, so different. Designed with the sculptured look to enhance your present decorating scheme, be it modern or traditional. Soft, sweeping lines, inspired by Venetian gondolas. Subtle, singing colours to glow like jewels in any room setting. Perfect big-set reception to enrich your listening, from Elvis right through to Elgar. All this is yours for a little £26/5/-, in the new, new Ekco 5-valve "Gondola" mantel radio, latest proud addition to the world-famous Ekco family.

In these modern colours: Adriatic Gold, Italian Ivory, Venetian Grey, Florentine Wine, Mediterranean Pink. Also available in Rome Red, Grotto Green, Cafe Tan and Sorrento Jade.

BACKED BY AEI AUSTRALIAN ELECTRICAL INDUSTRIES PTY. LIMITED MAKERS OF FAMOUS Hotpoint APPLIANCES

AEJ7.5PC

The advertisement in question from Women's Weekly, August 6th, 1958, from: https://trove.nla.gov.au/aww/read/222706



The side-bar was made from a small piece of MDF. The blotches in the hardened epoxy were due to air holes.

Cleaning up and repairing the case was a labourious task. You would never notice that a large chunk of the case had to be remade.

These holes are not gas released during the epoxide reaction with the amine setting agent. The chemistry of the setting is an addition reaction without by-products. The gas holes are air that mixes with the filler when the two parts are blended.

The whole repaired case was undercoated then sprayed with Dulux semi-gloss Paperbark enamel paint. The result is a fair match to the original. I shared the outcome of this repair with some radio mates and was well repaid for the restoration effort by the complimentary feedback. The most succinct response was "OMG!".

Ekco and Hotpoint history

The Ekco brand derives from its founder's name, Eric Kirkham Cole. In the 1930s Cole began making valve radios in the UK that were technically excellent and visually distinctive.

The 1934 Ekco model AD65 is a collector's classic. WW2 led to the Ekco company manufacturing advanced communication and electronic guidance systems. After the war, the company turned to manufacturing white goods under the corporate title of Associated Electrical Industries (AEI). The Ekco Gondola radio featured here also has an AEI logo on the front at the base.

However, the Australian AEI is subtly different to the UK company name. The rear panel of the Gondola radio proclaims "Manufactured by EDISWAN-EKCO (AUST) PTY LTD, distributed by AUSTRALIAN ELECTRICAL INDUSTRIES PTY LTD".

This company was registered in 1956 with an authorised capital of £1 million and based in Sydney. The Ekco UK company put up part of the capital and the rest came from General Electric US.

The Ekco Gondola was only manufactured and sold in Australia. Radio production was a minor focus of the company because the main focus was to manufacture variants of the successful UK Ekco range of television sets.

As proclaimed in their advertising, the Gondola radio was manufactured by "the makers of famous Hotpoint appliances". The Hotpoint brand had an interesting origin in the US, starting as a niche electrical product.

Before internal electrical heating, clothes-irons were heated on a stove-top or similar heat source. With electrical heating it became possible to raise the front of the sole plate to a higher temperature than the rest. This "Hotpoint" was avidly welcomed by housewives. Eventually Hotpoint became part of the General Electric conglomerate.

Prior to 1956, radios sold in Australia for GE were branded AGE/Hotpoint/Bandmaster and were made by AWA. Australian General Electric (AGE) withdrew from Australian Electrical Industries because American anti-trust legislation required GE in the US to divest itself of the Australian company. Consequently, the UK company EDISWAN-EKCO became the owner, although it seems that AEI were still permitted to use the Hotpoint brand.

This brief history has been collated from several sources. Although I believe the information is accurate, any corrections would be welcome.

The Ekco Gondola is a radio I had aspired to collecting for some time. This one has now joined my short list of favourites. **SC**

SILICON CHIP .com.au/shop ONLINESHOP

Looking for a specialised component to build that latest and greatest Silicon Chip project? Maybe it's the PCB you're after? Or a pre-programmed micro? Or some other hard-to-get "bit"? The chances are they are available direct from the Silicon Chip Online Shop.

- PCBs are normally IN STOCK and ready for despatch when that month's magazine goes on sale (you don't have to wait for them to be made!).
- Even if stock runs out (eg, for high demand), in most cases there will be no longer than a two-week wait.
- One low p&p charge: $10 per order, irregardless of how many items you order! (AUS only: overseas clients – check the website for a postage quote).
- Our PCBs are beautifully made, very high quality fibreglass boards with pre-tinned tracks, silk screen overlays and where applicable, solder masks.
- Best of all, subscribers receive a 10% discount on purchases! (Excluding subscription renewals and postage costs)

HERE'S HOW TO ORDER:

All prices are in AUSTRALIAN DOLLARS ($AUD)

- ✔ **INTERNET** (24 hours, 7 days): Log on to our secure website – siliconchip.com.au, click on "SHOP" and follow the links
- ✔ **EMAIL** (24 hours, 7 days): email silicon@siliconchip.com.au – Clearly tell us what you want and include your contact and credit card details
- ✔ **MAIL** (24 hours, 7 days): PO Box 139, Collaroy NSW 2097. Clearly tell us what you want and include your contact and credit card details
- ✔ **PHONE** (9am-5pm AET, Mon-Fri): Call (02) 9939 3295 (INT +612 9939 3295) – have your order ready, including contact and payment details!

YES! You can also order or renew your Silicon Chip subscription via any of these methods as well!

PRE-PROGRAMMED MICROS

Micros cost from $10.00 to $20.00 each + $10 p&p per order#

$10 MICROS

PIC12F617-I/P	Temperature Switch MK2 (June'18), Recurring Event Reminder (Jul'18)	
	Door Alarm (Aug'18), **Steam Whistle (Sept'18), White Noise Source (Sept'18)**	
PIC12F675-I/P	UHF Remote Switch (Jan09), Ultrasonic Cleaner (Aug'10)	
	Ultrasonic Anti-fouling (Sep'10), CricketFrog (Jun'12), Do Not Disturb (May'13)	
	IR-to-UHF Converter (Jul'13), UHF-to-IR Converter (Jul'13)	
	PC Birdies *2 chips – $15 pair* (Aug'13), Driveway Monitor Receiver (July'15)	
	Hotel Safe Alarm (Jun'16), Battery Charger Controller (Nov'16)	
	Kelvin the Cricket (Oct'17), Triac-based Mains Motor Speed Controller (Mar'18)	
	Heater Controller (Apr'18)	
PIC12F675-E/P	Courtesy LED Light Delay for Cars (Oct'14), Fan Speed Controller (Jan'18)	
PIC16F1455-I/P	Microbridge (May'17), USB Flexitimer (June'18)	
PIC16F1507-I/P	Wideband Oxygen Sensor (Jun-Jul'12)	
PIC16F88-E/P	Hi Energy Ignition (Nov/Dec'12), Speedo Corrector (Sept'13)	
	Auto Headlight Controller (Oct'13), 10A 230V Motor Speed Controller (Feb'14)	
	Automotive Sensor Modifier (Dec'16)	
PIC16F88-I/P	Projector Speed (Apr'11), Vox (Jun'11), Ultrasonic Water Tank Level (Sep'11)	
	Quizzical (Oct'11), Ultra LD Preamp (Nov'11), 10-Channel Remote Control	
	Receiver (Jun'13), Revised 10-Channel Remote Control Receiver (Jul'13)	
	Nicad/NiMH Burp Charger (Mar'14), Remote Mains Timer (Nov'14)	
	Driveway Monitor Transmitter (Jul'15), Fingerprint Scanner (Nov'15)	
	MPPT Lighting Controller (Feb'16), 50/60Hz Turntable Driver (May'16)	
	Cyclic Pump Timer (Sep'16), 60V 40A DC Motor Speed Controller (Jan'17)	
	Pool Lap Counter (Mar'17), Rapidbrake (Jul'17), Deluxe Frequency Switch (May'18)	
PIC16LF88-I/P	Garbage Reminder (Jan'13), Belibird (Dec'13), GPS Analog Clock Driver (Feb'17)	
PIC16LF88-I/SO	LED Ladybird (Apr'13)	
PIC16LF1709-I/SO	Battery Cell Balancer (Mar'16)	

$15 MICROS

PIC16F84A-20I/P	Programmable Ignition Timing Module (Jun99), Fuel Mixture Display (Sept00)
	Oscar Naughts And Crosses (Oct'07), UV Lightbox Timer (Nov'07)
PIC16F877A-I/P	6-Digit GPS Clock (May-Jun'09), 16-bit Digital Pot (Jul'10), Semtest (Feb-May'12)
PIC16F2550-I/SP	Batt Capacity Meter (Jun'09), Intelligent Fan Controller (Jul'10)
PIC16F6450-I/P	Multi-Purpose Car Scrolling Display (Dec'08), GPS Car Computer (Jan'10)
PIC32MM0256GPM028-I/SS	Super Digital Sound Effects (Aug'18)
PIC32MX170F256B-50I/SP	GPS Tracker (Nov'13), Micromite ASCII Video Terminal (Jul'14)
	Micromite Mk2 (Jan'15) + *47µF*, Low Frequency Distortion Analyser (Apr'15)
	Micromite LCD BackPack (either version) (Feb'16), GPS Boat Computer (Apr'16)
	Micromite Super-Clock (Jul'16), Touchscreen Voltage/Current Ref (Oct-Dec'16)
	Micromite LCD BackPack V2 (May'17), Deluxe eFuse (Aug'17)
	Micromite DDS for IF Alignment (Sept'17), Tariff Clock (Jul'18)
PIC32MX170F256D-50I/PT	44-pin Micromite MK2
PIC32MX795F512H-80I/PT	Maximite (Mar'11), miniMaximite (Nov'11), Colour Maximite (Sept/Oct'12)
	Touchscreen Audio Recorder. (Jun/Jul 14)
dsPIC33FJ64MC802-E/SP	Induction Motor Speed Controller (revised) (Aug'13)
	$20 MICROS
PIC32MX470F512H-I/PT	Stereo Audio Delay/DSP (Nov'13), Stereo Echo/Reverb (Feb 14)
	Digital Effects Unit (Oct'14)
PIC32MX695F512L-80I/PF	Colour MaxiMite (Sept'12)
PIC32MX470F512H-120/PT	Micromite PLUS Explore 64 (Aug 16), Micromite Plus LCD BackPack (Nov16)
PIC32MX470F512L-120/PT	Micromite PLUS Explore 100 (Sep-Oct'16)
dsPIC33FJ128GP802-I/SP	Digital Audio Signal Generator (Mar-May'10), Digital Lighting Cont. (Oct-Dec'10)
	SportSync (May'11), Digital Audio Delay (Dec'11),
	Quizzical (Oct'11), Ultra-LD Preamp (Nov'11), LED Musicolor (Nov'12)

When ordering, be sure to select BOTH the micro required AND the project for which it must be programmed.

SPECIALISED COMPONENTS, HARD-TO-GET BITS, ETC

P&P – $10 Per order#

STEAM WHISTLE / DIESEL HORN *(SEPT 18)*
Set of two programmed PIC12F617-I/P micros **$15.00**

SUPER DIGITAL SOUND EFFECTS KIT *(AUG 18)*
PCB and all onboard parts (including optional ones) but no SD card, cell or battery holder **$40.00**

RECURRING EVENT REMINDER PCB+PIC BUNDLE *(JUL 18)*
PCB and programmed micro for a discount price **$15.00**

USB PORT PROTECTOR COMPLETE KIT *(MAY 18)*
All parts including the PCB and a length of clear heatshrink tubing **$15.00**

AM RADIO TRANSMITTER *(MAR 18)*
MC1496P double-balanced mixer IC (DIP-14) **$2.50**

VINTAGE TV A/V MODULATOR *(MAR 18)*
MC1374P A/V modulator IC (DIP-14) **$5.00**
S8K-71K coil former pack **(two required)** **$5.00 ea.**

ALTIMETER/WEATHER STATION *(DEC 17)*
Micromite 2.8-inch LCD BackPack programmed for the Altimeter project **$65.00**
GY-68 barometric pressure and temperature sensor module (with BMP180, Cat SC4343) **$5.00**
DHT22 temperature and humidity sensor module (Cat SC4150) **$7.50**
Enclosure 1A/500mA Li-ion/LiPo charger board **(optional)**, Cat SC4308) **$15.00**

PARTS FOR THE 6GHz+ TOUCHSCREEN FREQUENCY COUNTER *(OCT 17)*
Explore 100 kit (Cat SC3834; no LCD included) **$69.90**
one ERA-2SM+ & one ADCH-80A+ (Cat SC1167; two packs required) **$15.00/pk.**

DELUXE EFUSE PARTS *(AUG 17)*
IPP60P03PHL04 P-channel mosfets (Cat SC4318) **$4.00 ea.**
BUK7909-75AIE 75V 120A N-channel SenseFet (Cat SC4317) **$7.50 ea.**
LT1490ACN8 dual op amp (Cat SC4319) **$7.50 ea.**

MICROBRIDGE COMPLETE KIT (CAT SC4264) *(MAY 17)*
PCB plus all on-board parts including programmed microcontroller (SMD ceramics for 10µF) **$20.00**

STATIONMASTER (CAT SC4187) *(MAR 17)*
Hard to get parts: DRV8871 IC, SMD 1µF capacitor and 100kΩ potentiometer with detent **$12.50**

MICROMITE LCD BACKPACK V2 – COMPLETE KIT (CAT SC4237) *(MAY 17)*
includes PCB, programmed micro, touchscreen LCD, ease-cut UB3 lid, mounting hardware, SMD Mosfets for PWM backlight control and all other on-board parts **$70.00**

ULTRA LOW VOLTAGE LED FLASHER (CAT SC4125) *(FEB 17)*
kit including PCB and all SMD parts, LDR and blue LED **$12.50**

SC200 AMPLIFIER MODULE (CAT SC4140) *(JAN 17)*
hard-to-get parts: Q8-Q16, D2-D4, 150pF/250V capacitor and five SMD resistors **$35.00**

VARIOUS MODULES & PARTS
2.8-inch touchscreen LCD module with SD card socket (Tide Clock, JUL'18) **$22.50**
ESP-01 WiFi Module (El Cheapo Modules, Part 15, APR'18) **$5.00**
WiFi Antennas with U.FL/IPX connectors (Water Tank Level Meter with WiFi, FEB'18):
SRI – **$12.50** – 2dBi (omnidirectional) –
NRF24L01+PA+NA transceiver with SMA connector and antenna (El Cheapo 12, JAN'18) **$5.00**
WeMos D1 Arduino-compatible boards with WiFi (SEPT'17, FEB'18):
ThingSpeak data logger – **$10.00** – WiFi Tank Level Meter (ext. antenna socket) – **$15.00**
Geeetech Arduino MP3 shield (Arduino Music Player/Recorder, VS1053, JUL'17) **$EE.00**
1nF 1% MKP 5mm lead spacing or ceramic capacitor (Wide-Range LC Meter, JUN'18) **$2.50**
MAX7219 LED controller boards (El Cheapo Modules, Part 7, JUN'17):
8x8 red SMD/DIP matrix display – **$5.00** – red 8-digit 7-segment display – **$7.50**
ADS83 DDS module (with gain control) (for Micromite DDS, APR'17) **$25.00**
AD9833 DDS module (no gain control) (El Cheapo Modules, Part 6, APR'17) **$15.00**
CP2102 USB-UART bridge **$5.00**
microSD card adaptor (El Cheapo Modules, Part 3, JAN'17) **$2.50**
DS3231 real-time clock with mounting spacers and screws (El Cheapo, Part 1, OCT'16) **$5.00**

MICROMITE PLUS EXPLORE 100 COMPLETE KIT (no LCD panel) *(SEP 16)*
(includes PCB, programmed micro and the hard-to-get bits including female headers, USB and microSD sockets, crystal, etc but does not include the LCD panel) (Cat SC3834) **$69.90**

THESE ARE ONLY THE MOST RECENT MICROS AND SPECIALISED COMPONENTS. FOR THE FULL LIST, SEE www.siliconchip.com.au/shop

All items subject to availability. Prices valid for month of magazine issue only. All prices in Australian dollars and include GST where applicable. **P&P prices are within Australia. O'seas? Please email for a quote**

PRINTED CIRCUIT BOARDS

NOTE: the listings below are for the PCB ONLY. If you want a kit, check our store or contact the kit suppliers advertising in this magazine. For unusual projects not available, some have specialised components available – see the kit suppliers.

NOTE: not all PCBs are shown here due to space limits but the SILICON CHIP Online Shop has boards going back to 2001 and beyond. For a complete list of available PCBs etc, go to *siliconchip.com.au/shop/8* Prices are PCBs only, NOT COMPLETE KITS!

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
PC BIRDIES	AUG 2013	08104131	$10.00
RF DETECTOR PROBE FOR DMMs	AUG 2013	08107131	$10.00
BATTERY LIFESAVER	SEPT 2013	11108131	$5.00
SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SIDRADIO (INTEGRATED SDR) Main PCB	OCT 2013	06109131	$35.00
SIDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
TINY TIM AMPLIFIER (identical Headphone Amp (Sept11))	OCT 2013	01109111	$20.00
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	08112131	$10.00
PORTAPAL D MAIN BOARDS	DEC 2013	01111131-3	$35.00/set
(for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above [Nov 2012/May 2013])			
LED Party Strobe (also suits Hot Wire Cutter [Dec 2010])	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
LiTi Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$12.50
BACKUP/MAINS BURP CHARGER	MAR 2014	14103141	$15.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTOR	APR 2014	07103141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16102141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	99106141	$10.00
MICROMITE ASCII VIDEO TERMINAL	JUL 2014	24107141	$7.50
FREQUENCY COUNTER ADD-ON	JUL 2014	04105141a/b	$15.00
TEMPMASTER MK3	AUG 2014	21108141	$15.00
44-PIN MICROMITE	AUG 2014	24108141	$5.00
OPTO-THEREMIN MAIN BOARD	SEP 2014	23108141	$15.00
OPTO-THEREMIN PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
ACTIVE DIFFERENTIAL PROBE BOARDS	SEP 2014	04107141/2	$10.00/set
MINI-I/I AMPLIFIER	SEP 2014	01101141	$10.00
COURTESY LIGHT DELAY	OCT 2014	05109141	$7.50
DIRECT INJECTION (D-I) BOX	OCT 2014	23109141	$5.00
DIGITAL EFFECTS UNIT	OCT 2014	01110131	$15.00
DUAL PHANTOM POWER SUPPLY	NOV 2014	18112141	$10.00
REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00
ONE-CHIP AMPLIFIER	NOV 2014	01109141	$5.00
TDR DONGLE	DEC 2014	04112141	$5.00
MULTISPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$50.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30.00/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015	SC2892	$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$5.00
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	1510815	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$8.00
DELTA CYCLETIME TIMER	MAR 2016	04102161	$5.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116011/2	$15.00
PRECISION 50/60Hz TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
1000B STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	10107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116061	$15.00
MICROMITE PLUS EXPLORE 64	AUG 2016	07108161	$5.00
CYCLIC PUMP/MAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$10.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SC200 AMPLIFIER MODULE	JAN 2017	01108161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
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Trouble fitting LC Meter into case

I have assembled the Wide-Range LC Meter project from the June 2018 issue (siliconchip.com.au/Article/11099) but I am having problems with the acrylic case. The pins from the LCD to CON4 and CON5 are not long enough to connect to the female headers on the shield. Are another two headers required to extend the pins on the LCD? (G. C., Stanthorpe, Qld)

● There seems to be considerable variation in the parts used to build this project (eg, the height of the stackable headers, the way the I²C backpack module is attached to the LCD etc).

This means that sometimes, the assembled unit doesn't fit in the case, despite the case being designed to suit the dimensions of our prototype unit.

Some constructors have needed to use jumper wires to extend the leads from the shield to the display. Or you could, as you suggest, use header pins to extend them. If you still can't make it fit, please send us a photo so we can come up with another idea.

Potential relay mix-up with LC Meter

I just finished building the Wide-range LC Meter (June 2018) using a Freetronics Eleven (the type with the ten-pin header) and have programmed it with no problems. It can measure high-value capacitors above about 3-4µF but not lower values. I suspect the relays are not working. Is it true that they are not used to measure high-value capacitors?

When measuring a 2200µF capacitor it reports it as 2.19mF. I thought mF and µF were the same. When measuring a 330µF capacitor it reads 328µF.

How can I check if the relays are working? They are all new ones from Jaycar. Has anyone actually gotten the Freetronics Eleven to work in this project? I don't have another Uno, so I can't check if that is the problem and I am not sure if there is something wrong with my shield board. (E. J. B., Bridgetown, WA)

● While mF (10^{-3}) is sometimes used to indicate a microfarad (µF; 10^{-6}). They aren't the same in this case.

On the relays, it does sound like they are the cause of the problem. Jaycar sells a 12V coil version of the specified relay and if they were to be mixed up with the 5V version, the shield would not work. Please check the markings on the relays to confirm that they are the correct 5V coil version.

If they are correct and it still doesn't work, please send us photos of the shield board (both sides) so we can look for other potential causes.

The reader came back and confirmed that the relays were the wrong type.

LC Meter display not working

I just finished building the Wide-Range LC meter (June 2018). Unfortunately, all I get on the LCD screen are white squares. Adjusting the contrast pot does not make any difference. The sketch appears to upload without errors. Can you give any suggestions? (A. F., Salamander Bay, NSW)

● The software addresses the I²C LCD on address 0x27 by default but some displays use address 0x3F. Please try changing the address to 0x3F on line 14 of the code to see if that helps. We're working on a revised version of the software that will automatically detect the address.

The other thing to look out for, besides obvious construction errors, is that it's sometimes possible for conductive components on the Arduino (especially the USB socket) to touch solder joints on the shield board and short connections out. If you think this may be a problem, stick some electrical tape on top of the offending components and try again.

LC Meter not recognising capacitors

I finished building the Wide-Range LC Meter project from the June 2018. This is my first time building an Arduino-based project so it took me a while to figure out how to install the libraries and upload the firmware but I managed to get it working, or so it seemed.

It does not seem to be able to tell the difference between an inductor and a capacitor. If I connect an inductor of known value (150µH) to the test terminals via short leads and alligator clips, I get a reading of 154µH which seems correct. But when I connect a capacitor to the terminals it still says the DUT is an inductor, even if I reboot it.

I have tried a few capacitor values from a 100nF ceramic capacitor to a 2200µF electrolytic capacitor but the device still insists it is an inductor and the capacitance values it does show on the second line bear no resemblance to the value of capacitor actually connected.

If I leave the device running with nothing connected to the test terminals the display reads as follows : L:250kH 10Hz C: 53.30pF 487213Hz

I am using the Altronics version of the Arduino Uno R3. I got C1, C2, the PCB and case pieces from the Silicon Chip Shop. All other components are as per the specifications. Are you able to give me a hint as to what might be going on here? (P. C., Adelaide, SA)

● The values you are getting for capacitance sound similar to the parasitic capacitance due to the PCB itself. We think that RLY3 is not closing, so when the LC Meter is trying to test for capacitance, it's not actually making a connection to the DUT. Check that RLY3 is the correct type and that its solder joints are good.

More problems with LC Meter case assembly

I finally got all of the parts together to build the Wide-Range LC Meter from the June 2018 issue. The assembly of the PCB shield went smoothly but I am having major problems putting it into the case.

The LCD I²C port expander board

does not line up properly to enable the LCD to attach. This seems due to the expander board not aligning with CON4 & CON5. Also, the trimpot stops the expander board from slotting into the shield. Finally, what are the extra holes in the bottom of the case for? (M. F., Wyongah, NSW)

- Despite the misalignment, you should still be able to get the assembly to fit in the case, as there is a fair bit of vertical room to spare. Some readers have suggested using Arduino-type jumper wires between the I²C module and the shield as they have mounted the I²C module very close to the LCD, which means that pins don't reach the sockets.

The extra holes in the base were originally added to help secure the Uno but are not necessary as the end piece holds the Uno firmly. As it is awkward to fit them, we decided to not use them in the final construction.

We suggest attaching the Uno and shield to the base and then attaching the LCD (with I²C module) to the top panel. This will make it easier to see how it all lines up and, if necessary, you can decide to use Arduino type jumper wires to make the connections between the LCD and shield rather than trying to plug it in directly.

Substitutes for obsolete toroidal cores

Just last week I dug out an old issue of *Electronics Australia*, the "Electronic Test Gear to Build" (1985) edition. I would like to build the 50V/5A Lab Power Supply Mk.2 in this magazine but I'm having trouble sourcing L1 (Neosid 17-146-10) and L2 (Neosid 17-143-10).

These are both powdered-iron toroidal cores. I can't find any data on them or anywhere to purchase them.

Unfortunately, Neosid do not have any record of the old part numbers which are quoted in the magazine and were unable to assist me.

I was able to find the dimensions for the Neosid 17-146-10 (L1) but not for L2. The specifications of L1 are: 44mm outer diameter, 24mm inner diameter and 16.5mm thickness. The closest core that I can find is 45mm OD, 27mm ID and 17mm thick.

I know what you might be thinking, why are you building a project that is so old? The reason is that I love the look of it. I feel it was an extremely well-designed linear switching supply. It is simple to assemble and not overly complicated. Also, a friend of a friend built one and he swears by it. He said its way better than a current model commercial switch-mode supply.

Can you suggest currently available powdered iron toroids I could substitute for the old ones, as well as the changes to the number of turns and wire gauge needed to produce inductors with equivalent performance to the original design? Any help would be most appreciated. (J. R., Werribee, Vic)

- The type numbers you quote are obsolete and Neosid use different numbers now but we do have some old data books with information on those parts. They give the following specifications:

Neosid 17-146-10 was 44 x 24 x 16.5mm with an A_L value of ~120nH. The best match we can find is Jaycar Cat LO1246 (42 x 22 x 17mm).

Neosid 17-143-10 was 33 x 20 x 10mm with an A_L value of ~60nH. The best match we can find is Altronics Cat L4534A (33 x 19.8 x 11.1mm). According to the Altronics data, the A_L value is 11nH for the L4534A.

Since the number of turns required is inversely proportional to the square root of the A_L value, you will need approximately 2.3 times as many turns for L2 compared to when the Neosid 17-143-10 core was used.

The Jaycar core specifications are unknown. From past experience, we estimate that the A_L value is around 90nH. So that means you need around 1.15 times as many turns (ie, 15% more) compared to that specified for the Neosid 17-146-10.

Note that the number of turns on these cores is not critical to the design.

Finding a humorous *EA* article

Way back when I was but a small lad, I remember reading a humorous article in *Electronics Australia* on how to build an atomic bomb.

I remember there were suggestions of things like using a lead-lined wheelchair when refining the uranium etc. It really did show what a difficult job it would be. I seem to remember it being in the early 90s but it could have been in the 80s. I was also into Omni magazine at the time.

It's almost impossible to find out anything about it from Google and I guess that's not surprising as the last thing you want to do is to make the task of building one any easier.

But I'd still very much like to read the article again if possible. I promise not to start any wars. So I'd like to order a copy of that article please. (B. S., via email)

- That article was published in the October 1980 issue of *Electronics Australia*. We can supply a photocopy or a scan of the article. You can order a photocopy at siliconchip.com.au/Shop/15/1415 or a scan (as a PDF download) at siliconchip.com.au/Shop/15/4689

Transistor gain values for Speedo Corrector

I purchased a back-issue copy of your September 2013 magazine for the Speedo Corrector Mk3 article (siliconchip.com.au/Article/4362), along with the PCB and programmed chip. The parts list includes a number of SMD transistors (BC846 and BC857). Should I buy the A, B or C versions? These have different h_{FE} values. Will BC846Cs and BC857Cs work? (G. Q., Warrnambool, Vic)

- The h_{FE} values for these transistors are not critical and the lowest specification types (A) can be used. The higher gain "C" versions you have suggested would also work fine.

Senator speakers with different configuration

I built a pair of the Senator loudspeakers which were described in your September 2015 issue (siliconchip.com.au/Series/291). They sound absolutely amazing! They are so good that I am going to replace my Quad ESL 63s with another pair of Senators.

However, due to my shelving position/width, I am planning to make some changes to the design for the new build. The original design is too deep to fit on my shelf, which is only 350mm wide. So I was wondering if I could fit the drivers in the side of the cabinet rather than on the face. The cabinet construction would be identical, so the volume would not change.

Would this result in the same sensitivity of 95dB/watt @ 1m? Maybe Allan Linton-Smith can help to answer this question. (B. D., Riverview, NSW)

● If you mount the drivers on the side of the cabinet then you will also need to change the baffle size and position so that it is still mounted directly behind the drivers. And because the baffle will be a different size and at a different distance from the drivers, the interaction will be different.

While the cabinet will have the same volume and the overall sensitivity should be the same, the pattern of reflections inside the cabinet will be quite different. The front-to-back distance will be much less and the reflector panel will be much closer to the back of the woofer and the tuned port.

Those changes might result in satisfactory sound but we cannot predict that. Indeed, we went through a number of changes in the design of the Senators until we were satisfied that the results were very good; you won't know until you have listened to it.

We are also concerned about how your modified Senator cabinets will be positioned in the room. Ideally, they should be placed well out of the corners of the room, with a metre or so from the walls to the cabinets. If this arrangement cannot be obtained, reflections from adjacent walls will lead to unnatural boosting and muddying of the bass.

What is a shorting block?

The parts list for the Wide-range LC Meter (June 2018; siliconchip.com.au/Article/11099) mentions a "2-pin header with shorting block". I cannot find this in local supplier catalogues. What is it and is it really necessary? (P. M., Hadfield, Vic)

● A shorting block is a small plastic block surrounding a piece of bent brass (or similar conductive material) which is used to make a connection between two adjacent pins.

These are typically used to select different options on a circuit. They are also known as "jumpers" or "jumper shunts" although a jumper can also refer to a piece of wire which is soldered directly to a PCB.

You can get them from Jaycar (Cat HM3240) or Altronics (Cat P5450) although in this case, you will probably already have one as it will come attached to the LCD I^2C adaptor board, where it is used to enable the backlight LEDs. You will need to remove it from this board since the corresponding header plugs into a socket on the LC Meter board, to provide mechanical support.

Since we are using that header for support, so that you can still enable the backlighting, we have wired it to a separate pin header on the LC Meter board. That is where you will place the shorting block that you remove from the I^2C Adaptor. That 2-pin header, mentioned in the parts list, is a standard 2-pin length of header strip.

These strips are available from Jaycar (Cat HM3211/HM3212), Altronics (Cat P5430) and most other electronics retailers.

Replacement for SMS Controller

Some years ago, I purchased and built a Jaycar kit for the SMS Controller (Silicon Chip, October-November 2004; siliconchip.com.au/Series/100). I used it with a Nokia 5110 phone. This has been reliable and very useful.

The phone recently ceased operating. Is there an update that would allow this project to work with a more

Senator Loudspeaker crossovers not operating as intended

I have just completed a pair of Senator 10-inch loudspeakers (September-October 2015; siliconchip.com.au/Series/291) using MDF boxes (which will be rounded and painted) and the original Celestion woofer and Celestion compression tweeter.

I find the sound immediately harsh and bright from the horn driver. Also, I need to turn the bass up as the bass driver seems unresponsive. I am using a 60/60 Playmaster amplifier.

Did the designer use much damping material inside the boxes? I have read that stuffing near the port can affect its performance and suppress the woofer.

Also, I mounted the crossover on the sloping panel – is that incorrect? Is the sound from the back of the woofer supposed to bounce off the sloping panel into the port?

If I wanted to adjust the attenuation resistors in the crossover, would it be sensible to maintain the overall voltage divider resistance of 7.65Ω and adjust the ratio so the voltage seen by the tweeter is reduced? At the moment, the voltage across the tweeter seems to be $0.26 \times V_{IN}$ (ie, $1.65 \div 7.65$).

Should I perhaps increase the 12Ω resistors to 13Ω (giving 6.5Ω when in parallel) and reduce the 3.3Ω resistors to about 2.3Ω (giving 1.15Ω in parallel)? Then the voltage across the tweeter would be $0.15 \times V_{IN}$. This might overdo the attenuation a bit but I could experiment with the divider. Thanks for your help. (G. M., Kogarah, NSW)

● There should be acoustic filling in the enclosure, as specified in the parts list, but it is quite a loose fill and would not be placed to obstruct the port.

We mounted the crossover on the base of the enclosure, as depicted in the diagram on page 36 (step six) of the September 2015 issue.

We are concerned that you say the bass is poor and the treble is overly bright and harsh.

Have you switched the tone controls on the Playmaster 60/60 out of circuit using the Defeat switch? That will ensure a flat frequency response from the amplifier.

We are also assuming that you have omitted the treble boost components involving switch S1 on the crossover PCB and that all components on the PCB are correct.

Where did you get the crossover inductor? If this is wound from wire that is too thin, it could have a higher resistance than expected and this would tend to shift the bass/treble balance towards the treble end. That would explain your observations.

Yes, you do need to maintain the overall impedance of the tweeter circuit or else the crossover frequency will be altered. Your suggested method to increase the tweeter attenuation will work but we are surprised that it is necessary.

up-to-date phone, or some sort of add-on GSM module? (R. L., New Zealand)

● We no longer have any GSM networks in Australia so that project is pretty much obsolete. But apparently, there are still GSM networks operating in New Zealand.

That being the case, we suggest you have a look at Arduino-Based GSM Remote Monitoring Station project in the March 2014 issue (siliconchip.com.au/Article/6743). It uses a GPRS shield and does not require a mobile phone.

Having said that, we suspect it will be cheaper and easier for you to simply buy a new Nokia 5110 from eBay. Also, note that we aren't sure if the GPRS shield used in our 2014 article is still available.

At some point, we plan to revisit that project and update it to use a 3G or 4G module. Another possible approach to sending messages over a mobile phone network is to combine a portable hotspot device with an ESP8266 Arduino board to send e-mails.

Parts for the 6GHz+ Frequency Counter

I would like to pass on my sincere congratulations on SILICON CHIP magazine reaching its recent 30th anniversary. I have been a follower of all things electronic since the early 1970s and was devastated when *Electronics Australia* magazine met a disappointing end. I must admit that I soon caught onto SILICON CHIP.

Congratulations to Leo Simpson, John Clarke, Jim Rowe and now Nicholas Vinen and others of the support team for this superior and informative magazine. It must be very difficult to keep on coming up with new ideas and projects month after month.

I am only a hobbyist but find most articles interesting in some way, but I do not really need another audio amplifier. At 71 years of age, my hearing is all but shot!

I have been a dedicated follower of Geoff Graham and the Maximite & Micromite and have most iterations of that device somewhere in my inventory. I have recently ordered the available components for the 6GHz+ Frequency Counter from the SILICON CHIP Online Shop and am in the process of making a significant order from Digi-Key.

I have found that sometimes the information included in some of the published project parts lists is a bit vague, especially for specialised not-so-common components. As a case in point, I have selected the following but am not sure if they meet the needs of the project:

- "47µH 1A 6x6mm SMD inductors": Digi-Key Cat 490-13133-1-ND (Murata MBH6045C-470MA=P3)
- "low-resistance SMD ferrite bead, 3216/1206": Digi-Key Cat 240-2410-1-ND (Laird HI1206P121R-10)

(W. G., Dunedin, New Zealand)

● Thanks for the encouraging words. Both the Digi-Key parts you have listed appear to match the specified PCB footprints and component specifications and should work fine.

There is a method to our madness. The reason that we gave somewhat vague descriptions of these components is that in the past, we have given a specific part number and source for a fairly generic component and then when that component is discontinued, we get multiple queries asking where the readers can find an equivalent part.

Depending on where you get the parts and what new parts become available after publication, you may be able to find a cheaper part with equivalent (even superior) specifications at a lower price. So we are loath to suggest

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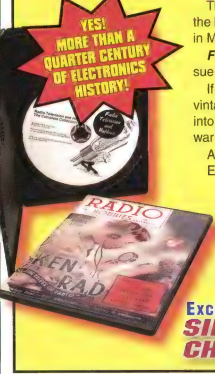

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a specific part when there may be dozens or even hundreds of different types that will work just as well.

We reasoned that if we gave all the critical details such as component value, size and current rating, constructors could then find the most suitable part that is available at the time. This does involve some searching, but the ability to find a suitable part given a set of specifications is quite a useful skill to have.

Ideally, we would like to give catalog codes for all the parts but it takes up a lot of space and also tends to clutter up the parts list, making it harder to read.

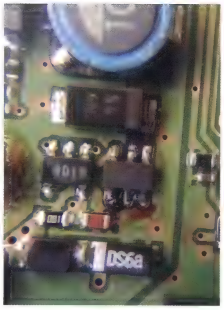
Help identifying SMD component

I am a retired electronics technician and SILICON CHIP subscriber trying to repair a low light camera. I enclose a picture. The two-pin SMD device marked S46N is across a low voltage supply and is short circuit.

The dark device near it has suffered too. I identified from its code S3B (no longer visible) that it was a TPC6102 P-channel Mosfet, for which I now have a replacement.

However, the S46N device is a mystery. Is it a Zener diode or an electrolytic capacitor? I have searched the internet but can't find it. Can you point me to a site which will help me identify it? The component labelled H108R is also unknown to me. (J. P., Waitara, NZ)

● It looks like an SMD diode rated at around 1A. We suggest you



download this PDF: http://caxapa.ru/thumbs/588912/smd-codes.pdf

This allows you to identify many (but probably not all) SMD components based on the codes printed on them. Unfortunately, many devices share the same code. The only device in that type of package (DO-214xx) with code S4 is the FS2G 400V 1.5A rectifier diode.

This PDF may also be of use to you: www.sphere.bc.ca/download/smd-codebook.pdf

It indicates that a device labelled H108 in an SOT-23-5 package is likely to be an SPX5205M5-L low-dropout adjustable regulator. The blackened device looks like a regulator in an SOT-23-6 package although it could be a Mosfet as you have suggested. We suggest that you check the PDFs to verify that there is no other possibility.

5 or 6 sensor wires for wideband O_2 sensor?

I have just finished building the Wideband Oxygen Sensor Controller (June-August 2012, siliconchip.com.au/Series/23) and have received the Bosch sensor from the recommended parts supplier (Bosch part number 0 258 017 123). The sensor supplied is a 5-wire device but based on Fig.3 on page 34 of the June 2012 issue, I was expecting a 6-wire device.

Can you please advise the changes to the plug/socket wiring connections and/or circuit changes to accept this sensor. (R. W., Bribie Island, Qld)

● While we show six connections in Fig.3, and the sensor connector has six pins, the sensor itself actually has five wires. The sixth pin in the connector is joined to one end of a resistor housed within the sensor connector housing (R_{CAL}). You do not need to make any changes to the sensor, wiring or circuit; simply complete the wiring as shown in the articles.

If for some reason you have cut the connector off the sensor then you will need to measure the value of R_{CAL}, between pins 1 and 5 (as shown in Fig.17 on page 36 of the July 2012 issue) and then connect a resistor or combination of resistors with a value as close as possible between pins 2 and 5 on the 8-pin circular socket (again, referring to Fig.17).

Starting air conditioner from generator with SoftStarter

I purchased a Yamaha 2kVA inverter generator to run my caravan air conditioner, which is a Coleman Mach 8 rated at 1220W and fitted with a soft start circuit. The generator has a maximum power output of 2.3kW but will not start the air conditioner.

Would either of your soft starter circuits from April or July 2012 help me start the air conditioner? (J. B., via email)

● It's possible, but unlikely that they would help, and they could potentially cause damage. It's difficult to give a definitive answer without doing any testing with the actual units.

Even with soft starting, the initial power drawn by a 1220W air conditioner is likely to be significantly more than 2kW.

If you limit it so that it can only draw 2.3kW during start-up, the air conditioner compressor may fail to start entirely and that could cause all sorts of problems. You could damage the air conditioner due to the compressor being stalled for a long period.

If you want to try it anyway, we suggest that you observe the operation of the system (ie, generator + soft starter + air conditioner) carefully the first few times it starts, especially when the compressor re-starts after a short period of being off.

This "hot starting" condition is usually when the highest current is drawn as the compressor requires a lot of current to overcome its internal friction.

Unfortunately, we think you probably will need a bigger generator, or at least one with a higher surge rating, especially considering that your air conditioner already has a soft start feature and yet the inrush current is still too high for the generator.

Note that non-inverter generators are generally better at handling brief overloads than inverter generators, even though their output waveform is usually a lot more distorted. SC

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Coming up in Silicon Chip

Touchscreen GPS Frequency Reference

This new GPS-disciplined frequency reference has three outputs which can be programmed to produce just about any frequency from 1.2MHz up to around 100MHz, as well as a disciplined 1pps output. It uses a temperature-compensated crystal oscillator inside an oven for maximum stability.

Designing the Cleverscope CS448

It took more than five years to go from idea to product and designer Bart Schroder ran into quite a few hurdles along the way, including ICs which didn't do what they were supposed to! The end result is a circuit which meets all of the strict initial design criteria. This is the story of how he achieved that.

Useless Box

We try to design useful devices but here is a project which, if built properly, is not only totally useless, it's so advanced that it's especially useless! Well, maybe that isn't strictly true since it provides a source of amusement, especially for kids.

Introduction to programming the Cypress CY8CKIT

This low-cost module incorporates a 32-bit microcontroller and a set of reprogrammable analog circuitry which can be used for a wide range of tasks. In this article we show you how to use the CY8CKIT-049 as a thermometer.

Four-channel DC Fan and Pump Controller

An updated speed controller for DC fans and pumps which runs from a 12V supply, can switch up to 40A of fans and/or pumps based on temperatures from up to four sensors. It's configured over a USB interface and can also provide real-time feedback on its operation.

Note: these features are planned or are in preparation and should appear within the next few issues of Silicon Chip.

The October 2018 issue is due on sale in newsagents by Thursday, September 27th. Expect postal delivery of subscription copies in Australia between September 25th and October 12th.

Notes & Errata

Wide-range Digital LC Meter, June 2018: we forgot to mention in this article that the software may need to be modified if your I^2C LCD module has a different address. The default address used is 0x27 which suits an I^2C board using the PCF8574T IC and no jumper options set. If your I^2C module uses a PCF8574AT IC, you will need to change that address (on line 14 of the sketch) to 0x3F.

We are in the process of developing a new version of the sketch which will automatically detect the display address. Once we have released that, you should not need to make any changes regardless of the I^2C address your module uses.

Low-cost Automotive Ammeter, Circuit Notebook, June 2018: while not strictly necessary, it is a good idea to add two 2.2µF 16V Tantalum capacitors, across the inputs and outputs of the Mornsun Switchmode Converter to reduce hash (see the data sheet for more details).

El Cheapo Modules 16 – ADF4351 4.4GHz digitally controlled oscillator, May 2018: a reader identified a bug in the code which caused the output frequency to be wrong in some cases (see the Mailbag section for more details). Revised software is available for download from the Silicon Chip website which fixes this bug.

6GHz+ Touchscreen Frequency Counter, October-December 2017: the power ground connection for op amp IC9 is made to pin 4 in both the circuit diagram and on the PCB but it should be to pin 5 instead. This can be fixed after assembling the board by running a short length of fine wire between pins 4 and 5 of the IC package. This will be fixed in the RevC PCB.

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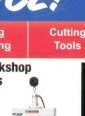

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